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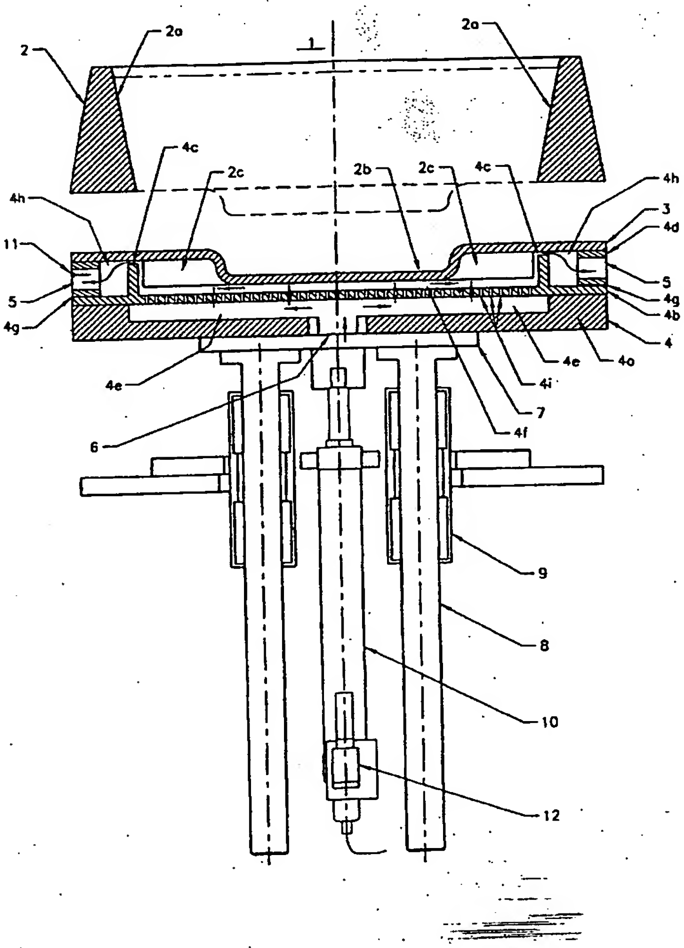

(57) Abstract: An apparatus for casting of metals comprising, a bottomless mould (2), a base component (3) for providing a mould bottom, and cooling means (4) for cooling the base component, wherein the base component is locatable in registry with the bottomless mould to define a mould cavity for receiving molten metal, the cooling means facilitating the cooling of the base component to solidify at least a portion of the molten metal in contact with the base component.

WO 02/22292 A1

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METAL CASTING PROCESS AND APPARATUS

Field of the Invention

The present invention relates to apparatus and processes for casting metals. In a particular non-limiting aspect, the invention relates to methods and apparatus particularly suitable for casting non-ferrous metals such as lead, tin, zinc, aluminium magnesium and their alloys. It also relates to components of such apparatus including moulds.

Background of the Invention

Typically, molten metals are cast into moulds to form ingots. The size of the ingot is dependent on the size of the mould. The molten metal is allowed to cool in the mould and on cooling adopts the general shape of the mould. Once the molten metal has sufficiently cooled, it can be removed from the mould. The ingots are then sold to manufacturers who in turn reheat the ingots to form molten metal, the molten metal being used as a feedstock for the manufacture of various products.

To achieve this simple procedure on a large scale, a typical system for casting of molten metals involves the use of a rotary casting table having a series of sections each containing a mould. A pouring station pours the requisite amount of molten metal into a mould located on the table. The mould is then indexed by the rotating movement of the table and is subsequently cooled at a cooling station generally by the application of a cooling fluid such as water. The cooling fluid can be sprayed onto the mould to facilitate cooling.

As the table turns, the mould is indexed to an extraction station where the now solidified ingot is removed from the mould and transferred to storage or for distribution to customers.

Although this and other methods are effective to a degree they often lead to the formation of central cavities in the ingot. As the molten metal cools, the partially formed ingot begins to pull away from the mould edges and bottom. These areas tend to cool more quickly than the middle portion and tend to create a central cavity within the ingot. The metal at the top of the ingot can solidify to form a cap when the top surface cools at a faster rate in comparison to the remainder of the molten metal. This in turn can lead to stresses on the top portion of the ingot which may result in the formation of cracks. The cracks can form a pathway to the cavity located within the ingot.

Ingots with a central cavity are potentially dangerous. In particular, if the ingots are stored outside, which is common practice, water or moisture can penetrate the ingot along a pathway formed by cracking, and can collect in a central cavity. Once an ingot containing moisture is re-melted, rapid vaporisation of the water in a confined space can cause an explosion which not only damages equipment, but potentially results in injury and loss of life.

The formation of a central cavity can be partly overcome by spraying the mould with cooling fluids such as water to ensure that the bottom and middle portions of the ingot solidify more quickly than the top. However, despite the use of such spraying techniques it has been found, this approach still leads to the formation of ingots with central cavities.

Additionally, as the mould base cools differentially with respect to the sides, stresses are induced upon the mould structure along specific areas located along the junctions joining the bottom of the mould with its sides. This in turn leads to the onset of structural weakness throughout the mould. Consequently the mould must be periodically replaced to ensure effective and safe casting operations.

Other known methods such as "vertical direct chill" casting can reduce the incidence of a central cavity, however these methods are expensive, labour intensive, require

more maintenance and are dangerous due to the potential for molten metal mixing with water.

The foregoing does not constitute an admission as to the state of common general knowledge in the art in Australia or the rest of the world as it existed as at the priority date of a claim of this application.

Disclosure of the Invention

The invention provides in one aspect an apparatus for casting of metals comprising,

a bottomless mould,

a base component for providing a mould bottom, and

cooling means for cooling the base component,

wherein the base component is locatable in registry with the bottomless mould to define a mould cavity for receiving molten metal, the cooling means facilitating the cooling of the base component to solidify at least a portion of the molten metal in contact with the base component.

Preferably the cooling means provides cooling for sufficient time to form a solidified metal base engaging the mould walls sufficient to support the weight of the remainder of the still molten metal, thereby allowing separation of the base component from the bottomless mould.

Preferably, the base component may be constructed of a material which can conduct heat readily away from the molten metal. The cooling means may comprise the base component and a base component cooling assembly. The base component is suitably a metal. Where the metal being cast is any one of aluminium, zinc, lead or magnesium the base component may suitably comprise copper, steel or cast iron. It may be coated with a material which reduces corrosion and oxidation by the air or the molten metal. In some instances the base component material may comprise aluminium. If aluminium is used it is preferred that the aluminium base material include a coating to resist corrosion and oxidation.

The base component may comprise the base component for a plurality of moulds. For example, where the base component comprises an elongate sheet of metal, several bottomless moulds may be sat upon the base component to form several mould cavities.

The fact that the base component is separate from the bottomless mould means that the rate of heat transfer from the bottomless mould to the cooled base component is less than would otherwise be expected if the two comprised an integral mould. Thus, the rate of cooling of the molten metal in contact with the interior walls of the bottomless mould will be less than the rate of cooling of the metal in contact with the base component. As a result the metal in contact with the base component solidifies first and forms a plug or base which closes off the bottom of the bottomless mould.

Suitably the bottomless mould has lesser heat transfer characteristics than the base component. Thus the bottomless mould may be comprised of a material which has a lower coefficient of heat transfer than the material of the base component which comes in contact with the molten metal. Alternatively or additionally the bottomless mould may include insulating material around at least a portion of its perimeter to reduce the effect of cooling caused by the outer walls being exposed to the atmosphere. To reduce the extent of cooling of the molten metal by the walls of the bottomless mould even further, a gasket may be interposed between the base component and the bottomless mould. The gasket may comprise insulating material. The insulating gasket reduces heat transfer between the bottomless mould and the cooled base component which in turn reduces the cooling effect of the walls of the bottomless mould on the molten metal.

A further approach to reduce the rate of cooling of molten metal not in direct contact with the base component is to provide a cover or roof over the top of the bottomless mould to reduce the cooling effect of air on the upper surface of the mould. When the metal being cast is magnesium a sealed cover has the additional advantage that it can provide a suitable chamber for the containment of a cover gas The gap between the

sealed cover and air may be filled with inert gas such as nitrogen to reduce the risk of oxidation. The roof or cover may include heating means to reduce the likelihood of the top surface of the metal cooling prematurely.

Preferably the bottomless mould has angled sides to aid in the retention of the base of a partially solidified ingot within the bottomless mould.

The cooling means may provide for the base component to be in contact with cooling fluids such as water. The cooling means may also include supply means to supply cooling fluid to the bottom of a partially formed ingot after the base component has been removed.

Preferably, the cooling fluids are at a temperature above the dew point to prevent condensation forming in the mould cavity. Alternatively or additionally the cooling fluids can be sprayed directly onto the base component and/or the bottom of an at least partially solidified ingot. The cooling fluids such as water may be sprayed onto the base component and/or the bottom of the ingot by a pump and spray nozzle or other appropriate means.

The cooling means may additionally or alternatively include the circulation of a cooling fluid such as water in contact with the base component by a pump or other appropriate means. Preferably a gallery formed by a base component cooling assembly mounted below and in contact with the bottomless mould directs the path of water in contact with the base component. Fluid enters the base component cooling assembly through an inlet, and circulates in contact with the base component in the region defined by the gallery. The now heated fluid is removed from the base component by an outlet. The fluid lowers the temperature of the base component by absorbing heat.

Preferably, the now heated fluid can be transferred via a passageway to a cooling area where it can be subsequently cooled and then if required, re-circulated through the base component cooling assembly.

Preferably, control monitoring means are located within the base component assembly. Preferably these monitoring means may be used to determine if the ingot is cooling correctly. They may operate by measuring the temperature of water after it has circulated through the base component cooling assembly.

Preferably, the base component can be located in registry with the bottomless mould by the use of a lift table. Preferably cylinders located under the lift table can be actuated by control means to bring the base component into registry with the bottomless mould. Control means can include pneumatic, hydraulic, electrical or mechanical means.

In a further aspect of the invention, a mould base is provided comprising a plurality of grooves located on the internal face of the mould base extending radially from a central point of the base. Thus in use the grooves define complementary ridges emanating from a central point of an ingot formed from the casting of solidifying material into the said mould, the solidifying material assuming the shape of the mould. An ingot produced from the mould has the ridges forming a cross shape on the ingot's lower surface. When the ingot is placed on a ground surface, the ridges provide clearance between the ground and the base of the ingot. The ridges are not long enough to extend to the edges of the ingot. This in turn allows a transporter such as a forklift to pick up the ingot from the bottom with the fork tynes of the forklift clear of the ends of the ridges.

The use of grooves in the mould base should assist with cooling because of the greater surface area. Whilst grooves are one method of providing an ingot in a shape which makes the ingot suitable for lifting by a forklift other ingot shapes known in the art may also be suitable. Examples of some alternative shapes will be shown in the accompanying drawings.

The invention provides in a further aspect, a method for casting of metals in a bottomless mould comprising the steps of,

placing a base component in registry with a bottomless mould to define a mould cavity for receiving molten metal,

casting the molten metal in the defined mould cavity, and

cooling the base component to solidify at least a portion of the molten metal.

Preferably, the cooling step can be for sufficient time to form a solidified metal base engaging the mould walls sufficient to support the weight of the remainder of the still molten metal.

The method may comprise the further step of removing the base component from the bottomless mould. This further step may be required if the depth of the mould is so great that the metal frozen above the base component shrinks and thereby loses intimate contact with the base component and hence the cooling effect of the base component is reduced. The depth of the molten metal cast can effectively determine whether it is preferred to improve cooling by removing the base component. Whilst this depth will vary from metal to metal, generally speaking a metal depth of at least 5cm, more preferably 10 cm, can be used as a rough rule of thumb for determining whether the base component should be removed prior to direct cooling of the bottom of the cast metal ingot.

Preferably, removal of the base component can occur after the formation of the solidified metal base engaging the mould walls sufficient to support the weight of the remainder of the still molten metal.

In another embodiment the invention provides an apparatus for the casting of metal comprising,

a mould assembly station including lifting means for bringing a base component into registry with a bottomless mould to form a mould cavity and for removing the base component out of registry with the bottomless mould,

a pouring station for pouring molten metal into the mould cavity,

cooling means for cooling the base component with cooling fluid and solidifying at least a portion of the molten metal in contact with the base component,

a cooling station for flowing cooling fluid directly against the molten metal which has solidified in contact with the base component after the base component has been brought out of registry with the bottomless mould, and

an extraction station for removing a solidified metal ingot from the bottomless mould.

The mould assembly station, pouring station and cooling means may all be at different locations, at the same location or a combination of any two of these possibilities.

Preferably the cooling means provides for sufficient time to form a solidified metal base engaging the mould walls sufficient to support the weight of the reminder of the still molten metal, thereby allowing removal of the base component from the bottomless mould.

The drive may include a driven linear or rotating platform. The bottomless moulds may be placed on the platform and indexed or conveyed to different stations. The platform may include a plurality of cradles for receiving the moulds. The drive may include control means to limit the disturbances to molten metal cast into the moulds.

The extraction station includes a removal means. The removal means may include an overhead crane or any other suitable pick and place apparatus. It may include one or more overhead rails for moving a crane trolley to a location above the drive. At this location it can pick up a solidified ingot and place it on a conveyor chain for transfer away from the drive.

Preferably one or more launders are provided for casting molten metal into the bottomless moulds. Each launder may fill a separate mould or may partially fill the same mould allowing the ingot to be poured in stages. The launder may have a plurality of outlets to pour more than one ingot at a time. The launder may be tiltable. It may include a compressible support such as spring loaded support or other equivalent, eg. hydraulically, electrically or pneumatically actuated support. The

launder support mechanism may be associated with control means for controlling the casting operation. The launder may be suitable for continuous and batch production.

Where the launder is used in association with the apparatus it will be located at a pouring station. The launder will operate to sequentially fill moulds indexed to the launder by the sequential drive.

Preferably a cooling station is located between the pouring station and the extraction station. It may extend for the entire travel of the bottomless mould between the two. Following removal of the base component the cooling station may provide for the bottom of the ingots to be in contact with cooling fluids such as water whilst being indexed to the delivery station. Cooling fluids such as water may be circulated around the ingots by a pump or other appropriate means. Alternatively, the cooling fluids such as water may be sprayed onto the ingots by a pump through a plurality of spray nozzles.

Preferably the apparatus includes a skimming station located between the pouring station and the extraction station. At the skimming station, dross may be removed from the molten metal cast into the mould either manually or with automatic machinery. When the apparatus includes both a skimming station and cooling station, the skimming station is preferably located between the pouring station and the cooling station. The skimming station may be integral with the pouring station.

As described above, the bottom component is removed once a solidified metal base engaging the wall of the mould has formed. Consequently, there is reduced stress on the mould since the bottom component and the upper portion of the mould are free to move independently. The cooling of the molten metal from the bottom can also reduce the incidence of producing metal ingots with internal cavities as the lower portions of the ingots solidify prior to the upper portions. The ability to apply a cooling fluid directly to the cast metal surface may allow the process to achieve a higher production rate than would otherwise occur if the base is not removed.

The incorporation of a bottomless mould as part of the apparatus can result in a casting apparatus capable of producing a substantially cavity free produce at a high production rate. The advantage of having a substantially cavity free ingot can reduce the subsequent operation costs to manufacturers of metallic products as the ingots do not require baking in an oven prior to use. Cavity free ingots are also safer to use as there is a reduced chance of water and molten metal interaction.

Detailed Description of the Preferred Embodiments

Figure 1 shows a cross-sectional view X-X of the apparatus shown in Figure 2 according to the invention;

Figure 2 is a plan view of a casting apparatus according to one embodiment including the apparatus of Figure 1;

Figure 3 is a side view of the apparatus shown in Figure 2;

Figure 4 is a cross-sectional view of the bottomless mould shown containing a partially solidified ingot of Figure 1 with a solidified metal base.

Figure 5 shows a perspective upside down view of an ingot cast using the apparatus shown in Figures 1 to 3;

Figures 6 to 8 show perspective views of alternative ingot shapes which may be cast according to the invention;

Figure 9 shows a plan view of an alternative casting apparatus according to the invention;

Figure 10 shows an elevational view of a first section of the casting apparatus of Figure 9 incorporating a carousel;

Figure 11 shows an elevational view of a second section of the casting apparatus of Figure 9 incorporating an ingot removal device and conveyor;

Figure 12 shows an elevational view of a demoulding assembly;

Figure 13 shows an elevational view of an alternative form of combined cooling facility and ingot removal facility; and

Figure 14 shows a plan view of an alternative form of combined cooling facility and ingot removal facility.

Referring to Figure 1, an apparatus 1 for casting molten metal according to the invention is shown. The apparatus 1 comprises a bottomless mould 2 generally rectangular or square in plan, with internal walls 2a and a cross shaped depression 2b. It also includes cooling fins 2c. The internal walls of the bottomless mould are sloped with respect to the vertical so that the ingot can be supported by the walls when the bottom of the ingot solidifies. A base component 3 and a cooling means 4 are arranged beneath the bottomless mould. The base component 3 is constructed of a heat conductive material, preferably copper. The base component and bottomless mould together define a mould cavity.

The cooling means includes a base component cooling assembly 4. The base component cooling assembly has outlets 5, and inlet 6. It comprises a base plate 4a which forms a closed cavity 4e with the perforated plate 4b mounted thereon. The perforations 4i in the perforated plate are arranged to allow fluid flow from the cavity 4e into the cooling gallery 4f formed between the bottom of the base component, the perforated plate and the baffle member 4c.

A spacer 4d and gasket 4g serve to space the baffle member from the base component and form an exit gallery 4h running around the outside of the cooling gallery.

A thermocouple 11 is located in the outlet to sense temperature changes in the cooling fluid. By sensing the temperature of cooling fluid through the outlet and comparing it with the temperature of the cooling fluid sensed to be entering the inlet it is possible to determine the degree of cooling and/or solidification of the ingot for a given fluid flow rate. It is therefore possible to determine the best time to remove the base component after a sealing plug of metal has formed in the bottom of the mould cavity. Cooling fluid such as water is circulated within the body of the base component by a pump (not shown) by entering via the inlet 6, following a path shown by the arrows and exiting via the outlets 5.

The base component 3 is located on a lifting table 7 supported by guide rails 8 located within guides 9. A lifting mechanism 10 engages the table 7.

In order to cast molten metal, the lifting mechanism 10 is actuated to lift the table 7 and hence the base component to bring it into registry with the bottomless mould to define an entire mould cavity for receiving molten metal. A lift sensor 12 senses when the base component abuts the bottomless mould and/or how much metal has been cast into the mould. The signals from the lift sensor can be used to control various operations such as the extent of lifting travel required of the lifting mechanism, the initiation of the casting of molten metal, the rate of casting and the cessation of casting when the required weight of metal has been cast.

The cooling means 4 facilitates the cooling of the base component 3 for a sufficient time to form a solidified metal base 40 engaging the mould walls 2a as shown in Figure 4. After the formation of the solidified base 40, the lifting mechanism 10 is reactivated to remove the base component 3 from the bottomless mould 2.

The formation of the solidified base 40 is accelerated by two factors. Firstly the base component 3 being made of heat conductive material including cooling fins 2c absorbs the heat from the molten metal contacting the base component 3. Secondly the circulating cooling fluid absorbs and removes the heat within the base component 3.

Figures 2 and 3 show an apparatus 20 for casting molten metal having a sequential drive for indexing bottomless moulds 2. The apparatus 20 consists of a rotating carousel 21 mounted by support arms 35 and 35a on a central support assembly 24. As is shown in Figure 2 the bottomless moulds 2 are located at points along the rotating carousel 21. The apparatus 20 in turn has several stations.

A casting station 22 includes the base component 3 previously described and a launder 23. The lifting mechanism 10 can be actuated to bring the base component 3 in registry with the mould walls 2a of the bottomless mould to define an entire mould cavity. Molten metal can now be introduced by the launder into the mould in the cavity as defined by the base component 3 and the bottomless mould 2.

The rotating carousel 21 is sequentially driven to index the mould containing the molten metal away from the casting station 22. The indexing is contingent on the formation of a solidified metal base 40 engaging the mould walls 2a. Once this occurs the solidified metal base 40 provides the bottom to the bottomless mould 2 and allows both the removal of the base component 3 by retraction of the lifting mechanism 10 and the indexing of the mould bottom containing partially solidified metal away from the casting station 22. As mentioned earlier the formation of the solidified metal base 40 is facilitated by the heat conductive properties of the base component 3 and the actions of the cooling means 4.

The carousel then rotates clockwise to index the bottomless mould 2 now filled with molten metal (but containing a solidified metal base 40) towards the extraction station 27.

As indexing occurs, the molten metal is indexed to a skimming station 25 to remove the dross from the molten metal cast into the mould.

Following removal of the dross, the bottomless mould 2 is again indexed towards the extraction station 27. A cooling station 32 lies between the casting station 22 and the extraction station 27. During indexing through the cooling stations the ingot bases are in contact with cooling fluids such as water. The cooling fluids such as water are sprayed onto the ingot bases by a pump (not shown) through a plurality of spray nozzles 26. The molten metal solidifies as it is indexed through the cooling station 32 to form a solid ingot within the body of the bottomless mould 1. A roof 37 is provided over the cooling station to prevent solidification of the top surface of the molten metal so that it solidifies from the bottom upwards. A reservoir 41 extends beneath the spray nozzles for collection and recycling of water.

After cooling the mould now containing an ingot, is indexed to an extraction station 27. The extraction station 27 includes a crane 28 in the form of a scissor lift 38 and overhead rails 29 for moving the crane 28 to a location above the rotating carousel 21.

At this location the crane 28 picks up the solidified ingot and places it on a conveyor chain 30 for transfer away from the rotary carousel 21. The conveyor may comprise a twin chain indexing conveyor which moves ingots to defined positions ready for removal by a forklift.

As is shown in Figure 2 the base component 3 has a plurality of grooves 31. The grooves 31 are located on the base component 3 face engaging the molten metal. Figure 5 shows how the grooves 31 form a cross shaped bottom ridge 50 on to the bottom of the ingot 51 as the molten metal solidifies.

The ridge provides clearance between the ingot bottom and a floor surface allowing the ingot to be picked up and removed by a forklift.

Figures 6 to 8 show conventional ingot shapes which may be case in various metal, particularly aluminium according to the invention. The ingot of Figure 6 is typically quite large being about 700kg in weight. It is known in the art as a TEEBAR. That shown in Figure 7 may have a weight in the range 300 to 1000kg and is known as a SOW. Finally that of Figure 8 may have a weight of about 3 to 50kg and is known as an INGOT.

Referring to Figures 9 to 12, the automatic casting machine 300 includes a carousel 301 provided with a pouring or casting station 290, a skimming station 291, a transfer station 292 and a delivery station 293 for ingot removal. A cooling area comprising a number of cooling tanks 294 is provided. This extends radially away from the transfer station. An ingot deposit station 295 having a delivery conveyor 296 and labelling and weighing station 357 are provided in association with the delivery station 293. An overhead crane assembly 297 connects the delivery station to the ingot deposit station.

The skimming station includes an automatic skimmer 302. Generally this will be in a form of a robot 303 operating a skimmer plate 304. A dross removal chute 308 is provided to dispose of dross removed by the automatic skimmer.

The transfer station 292 includes a first overhead crane assembly 315. The crane has a pair of pivotable crane arms 316 operable by an actuator 326 acting through toggle arms via the pivot 327. As can be seen from the drawing when the arms are in the vertical configuration they grab underneath the lip of the bottomless mould to support and carry the bottomless mould carrying a partially or fully solidified ingot. However, when the toggle arms are operated in the reverse direction, the crane arms splay outwardly to let go of the mould.

The crane is provided with wheels 318 which run along the rails 319 so that it can move from above the transfer station 292 to the cooling tanks 294 where it can pick up and put down moulds. The base 12 of each of the cooling tanks is fitted with a water cooling system 317. A lid 433 is also provided for each cooling tank.

The first crane lifting assembly including actuator, toggle arms and crane arms is pivotally mounted via the pivot 353 for reasons to become apparent. The hydraulic cylinders 325 act to raise and lower the crane lifting assembly.

The second overhead crane assembly 350 includes hydraulic cylinders 355 for raising and lowering the block lifting assembly 199 and the cast block or ingot 200 attached thereto. The crane moves between a position above the delivery station 293 to one above the delivery conveyor 296. It includes wheels 352 and rails 351 for this purpose.

The carousel itself includes four mould cradles 310 for supporting the base components 400 and the bottomless moulds 401 mounted on the base components. It also includes a support and drive mechanism 311 and a weighing assembly for weighing the metal being cast into a mould as it is cast by the launder 50. The carousel is controlled automatically and is powered by a variable speed electronic drive.

Water sprays 410 are arranged to spray water onto the base component. A reservoir 312 collects the sprayed water for recycling. The water sprays and reservoir may extend from the pouring station to the transfer station.

In a typical sequence of operations using the casting machinery shown in Figures 9 to 12, molten metal is poured from a fixed launder (not shown) into the tilting launder 50. The rate of delivery of molten metal through the funnel 52 of the tilting launder is controlled by the degree of tilt which is in turn dependent upon the weight of metal in the launder.

When the weight of metal poured into the mould cavity defined by the base component and bottomless mould as measured by the launder reaches a predetermined limit, the hydraulic cylinder 54 lifts the launder clear of the mould.

The carousel then rotates anti-clockwise to index the mould cavity now filled with molten metal to the skimming station 291. The acceleration and deceleration of the variable speed drive rotating the carousel is carefully controlled each time it indexes the moulds to a different station in order to minimise the surface wave actions induced in the molten metal.

The robot 303 of the automatic skimmer 302 moves a skimmer plate 304 across the surface of the mould to pick up dross and dump it in the dross removal chute.

Following removal of dross, the mould cavity is indexed to the transfer station 292. At the transfer station the overhead crane 315 through operation of the hydraulic cylinders 325 lowers the crane arms which are held in the splayed position by the actuator 326 as they are being lowered.

When the crane arms are in registry with the lip of the bottomless mould, the actuator 326 operating through a pivot by a toggle action moves the crane arms into gripping registry with the lip of a bottomless mould and the bottomless mould containing

partly solidified metal is subsequently lifted by actuation of the hydraulic cylinders 325 clear of the cradle 310 and the base component supported by the cradle.

The crane then travels along the rails 319 until it approaches an empty cooling tank 294. It decelerates to a stop above the empty tank and lowers the bottomless mould so that the base of the solidified metal directly contacts the water in the tank. The acceleration and deceleration of the crane is controlled to reduce disturbance of the molten metal. The pivot 353 provided in association with the assembly for holding the arms of the crane allows the crane holding the bottomless mould to freely sway from the vertical during the acceleration and deceleration phases. This swaying action in association with controlled acceleration/ deceleration serves to reduce the amount of disturbance felt by the molten metal in the mould during the travel to the cooling tank and hence minimises ripples.

After the bottomless mould has been placed in a cooling tank and the crane arms are retracted to their uppermost position, the crane moves to a tank where the mould has had sufficient time for cooling, and after the lid 433 has been tilted aside, picks up the bottomless mould containing a solidified ingot and deposits it on the base component 400 mounted on the cradle 310 of the carousel at the transfer station.

This cooled mould cavity containing the solidified ingot is then indexed to the delivery station 293 by the carousel. An extra station 358 may be provided for the placement of bottomless moulds for any desired purpose such as mould replacement.

At the delivery station a demoulding assembly 500 as shown in detail in Figure 12 pushes the ingot 200 upward out of the bottomless mould so that the sides of the ingot are accessible to be gripped by the arms of the block lifting assembly 199 and moved by the crane to the delivery conveyor 296. The empty mould cavity is indexed by the carousel to the casting station.

Referring to Figure 12, the demoulding assembly 450 is located between the delivery station 293 and ingot deposit station 295 described with reference to Figures 9 to 11.

The demoulding assembly 450 comprises a support table 451 which supports a secondary cradle assembly 452 movable between the position shown at the right of the drawing in dark lines to the position shown at the left in light lines.

The secondary cradle assembly includes a horizontal platform 453 provided with an elevation pad 454. It also includes a support pad 455 for supporting the base of the bottomless mould. The support pad extends through the plane of the page and at two places in a direction to the right and parallel to the plane of the page to underlie sufficient of the bottomless mould to provide stable support therefore when it is in position shown in the drawing.

The steps involved in operation of the demoulding assembly are listed below:-

(i) Initially the secondary cradle assembly is in the position shown in faint lines at the left of the page when a mould cavity containing an ingot is indexed to the delivery station 293 by the carousel 301.

(ii) The block lifting assembly 199 lifts the bottomless mould 401 containing an ingot away from the base component 400.

(iii) The secondary cradle assembly moves to the right so that the elevation pad 455 underlies the bottom of the ingot and the support pad 455 underlies the bottomless mould.

(iv) The block lifting assembly lowers and releases the bottomless mould so that the elevation pad 454 forces the ingot upwards to partially extend above the bottomless mould.

(v) The block lifting assembly moves to grip and raise the ingot 200 and the crane assembly 350 moves the ingot to be deposited on the delivery conveyor 296.

(vi) The block lifting assembly is returned to raise the bottomless mould from the secondary cradle assembly.

(vii) The secondary cradle assembly is retracted.

(viii) The block lifting assembly lowers the empty bottomless mould onto the base component and retracts.

(ix) The carousel indexes the next mould cavity containing an ingot to the delivery station and the process is repeated.

Referring to Figures 13 and 14 there is shown an alternative apparatus according to the invention in which the need for a separate delivery station on the carousel as has been described with reference to the earlier drawings is avoided by virtue of the fact that the delivery station is used to deliver bottomless mould cavities containing partially solidified ingots to a combined cooling and demoulding facility.

Thus in Figures 13 and 14, the transfer station 600 is provided with a primary overhead crane assembly 603 for removing and replacing mould cavities 601 from the carousel.

Initially the primary overhead crane assembly takes a bottomless mould containing a partially solidified ingot from the carousel leaving the base component of the mould cavity in place on the carousel.

The primary overhead crane assembly then deposits the bottomless mould in a cooling facility. It goes on to pick up a fully cooled bottomless mould from the cooling facility and moves it to a demoulding facility where a solidified ingot is pushed out of the bottomless mould and is picked up by the secondary overhead crane assembly 605 and taken to the delivery conveyor 606.

The primary overhead crane assembly then picks up the empty bottomless mould left at the demoulding facility 604 and returns it to rest upon a base component originally left at the transfer station to reform a mould cavity. This is indexed back to the pouring or casting station and the entire cycle as per the previous general description repeated.

Whilst the description has often referred to the use of a carousel for indexing bottomless moulds, it is to be appreciated that any form of sequential drive properly configured may be used in place of a carousel.

The word "comprising" and forms of the word "comprising" as used in this description does not limit the invention claimed to exclude any variants or additions. Modifications and improvements to the invention will be readily apparent to those skilled in the art. Such modifications and improvements are intended to be within the scope of this invention.

Claims

1. An apparatus for casting of metals comprising,

a bottomless mould

a base component for providing a mould bottom, and

cooling means for cooling the base component,

wherein the base component is locatable in registry with the bottomless mould to define a mould cavity for receiving molten metal, the cooling means facilitating the cooling of the base component to solidify at least a portion of the molten metal in contact with the base component.

2. Apparatus according to claim 1 wherein the cooling means comprise the base component and a base component cooling assembly, both in combination forming a gallery for circulation of cooling fluid in contact with the base component.

3. Apparatus according to claim 1 wherein the bottomless mould has sides which are angled so that they become closer together nearer the bottom of the bottomless mould whereby to aid in the retention of the base of a partially solidified ingot within the bottomless mould.

4. Apparatus according to claim 3 comprising,

a mould assembly station including lifting means for bringing the base component into registry with the bottomless mould to form a mould cavity and for moving the base component out of a position of registry with the bottomless mould,

a pouring station for pouring molten metal into the mould cavity,

a cooling station for flowing cooling fluid directly against the molten metal which has solidified in contact with the base component after the base component has been brought out of registry with the bottomless mould, and

an extraction station for removing a solidified metal ingot from the bottomless mould.

5. Apparatus according to claim 4 comprising a sequential drive for indexing the bottomless mould to the different stations in a continuous repeatable circuit.

6. Apparatus according to claim 5 wherein the sequential drive comprises a carousel.

7. Apparatus according to claim 6 wherein the pouring station and mould assembly station are located at the same indexed position on the carousel.

8. Apparatus according to claim 5 wherein the cooling means comprise the base component and a base component cooling assembly, both in combination forming a gallery for circulation of cooling fluid in contact with the base component.

9. Apparatus according to claim 5 wherein the cooling station comprises,

a plurality of nozzles for spraying water onto the base of a partially solidified ingot,

at least one of a roof for covering the upper surface of the molten metal in the bottomless mould and heating means for heating the upper surface of the molten metal in the bottomless mould, and

a reservoir arranged beneath the plurality of nozzles for receiving water deflected off the base of the partially solidified ingot.

10. Apparatus according to claim 1 wherein the base component comprises a mould base provided with a plurality of grooves located on a surface of the base component forming the interior of the mould cavity, the grooves extending radially from a central point on the base component.

11. Apparatus according to claim 10 wherein the grooves form a cross.

12. Apparatus according to claim 1 wherein the base component includes a plurality of cooling fins.

13. Apparatus according to claim 5 wherein the extraction station comprises a lift for removing an ingot from the bottomless mould and an indexing conveyor arranged to receive an ingot from the lift.

14. Apparatus according to claim 13 wherein the lift comprises a scissor lift.

15. Apparatus according to claim 5 wherein the lifting means include a weight sensor for sensing the weight of molten metal cast into the mould cavity.

16. A method for casting of metals in a bottomless mould comprising the steps of,

placing a base component in registry with a bottomless mould having mould walls to define a mould cavity for receiving molten metal,

casting the molten metal in the defined mould cavity, and

cooling the base component to solidify at least a portion of the molten metal.

17. A method according to claim 16 wherein,

the cooling step is for sufficient time to form a solidified metal base from the molten metal for engaging the mould walls to support the weight of the remainder of the still molten metal,

the base component is removed to permit direct access to the bottom of the solidified metal base, and

cooling fluid is applied directly to the solidified metal base.

18. A method according to claim 17 wherein the depth of the molten metal cast into the mould cavity is at least 5cm.

19. A method according to claim 18 wherein the depth of the molten metal cast into the mould cavity is at least 10cm.

20. Apparatus according to claim 1, having a sequential drive for indexing moulds provided thereon to a plurality of stations, the plurality of stations including:-

a pouring station for casting molten metal into the mould cavity;

a separate transfer station provided with transfer means for lifting the bottomless mould containing a partially solidified molten metal cast into the mould at the pouring station to a cooling facility separate from the sequential drive allowing for the static cooling of the molten metal in an area remote from the sequential drive and for returning the bottomless mould to the sequential drive.

21. Apparatus according to claim 20 wherein the transfer means are arranged to lift the bottomless mould from the sequential drive, leaving the base component on the sequential drive and to return the bottomless mould containing a solidified ingot after cooling at the cooling facility to the transfer station to rest on a base component the apparatus also comprising an extraction station provided with removal means for removing a solidified ingot from the mould cavity before the mould cavity is returned to the pouring station by the sequential drive.

22. Apparatus according to claim 20 including a skimming station located intermediate the pouring station and transfer station, the skimming station being provided with means for skimming dross from molten metal contained in a mould cavity.

23. Apparatus according to claim 20 wherein the pouring station includes a launder for delivering molten metal to a mould cavity and weighing means for weighing the weight of metal delivered to the mould, the launder having valve means which are adapted to cut-off delivery of molten metal to the mould when the weighing means registers a weight of metal in the mould at or beyond a predetermined weight limit.

24. Apparatus according to claim 20 wherein,

the cooling facility includes an extraction station for removing a solidified metal ingot from the bottomless mould and transferring it to a discharge area leaving an empty bottomless mould,

the transfer means is arranged to return the empty bottomless mould to register with a base component held on the sequential drive at the transfer station to form a mould cavity, and

the sequential drive is arranged to index the mould cavity to the pouring station.

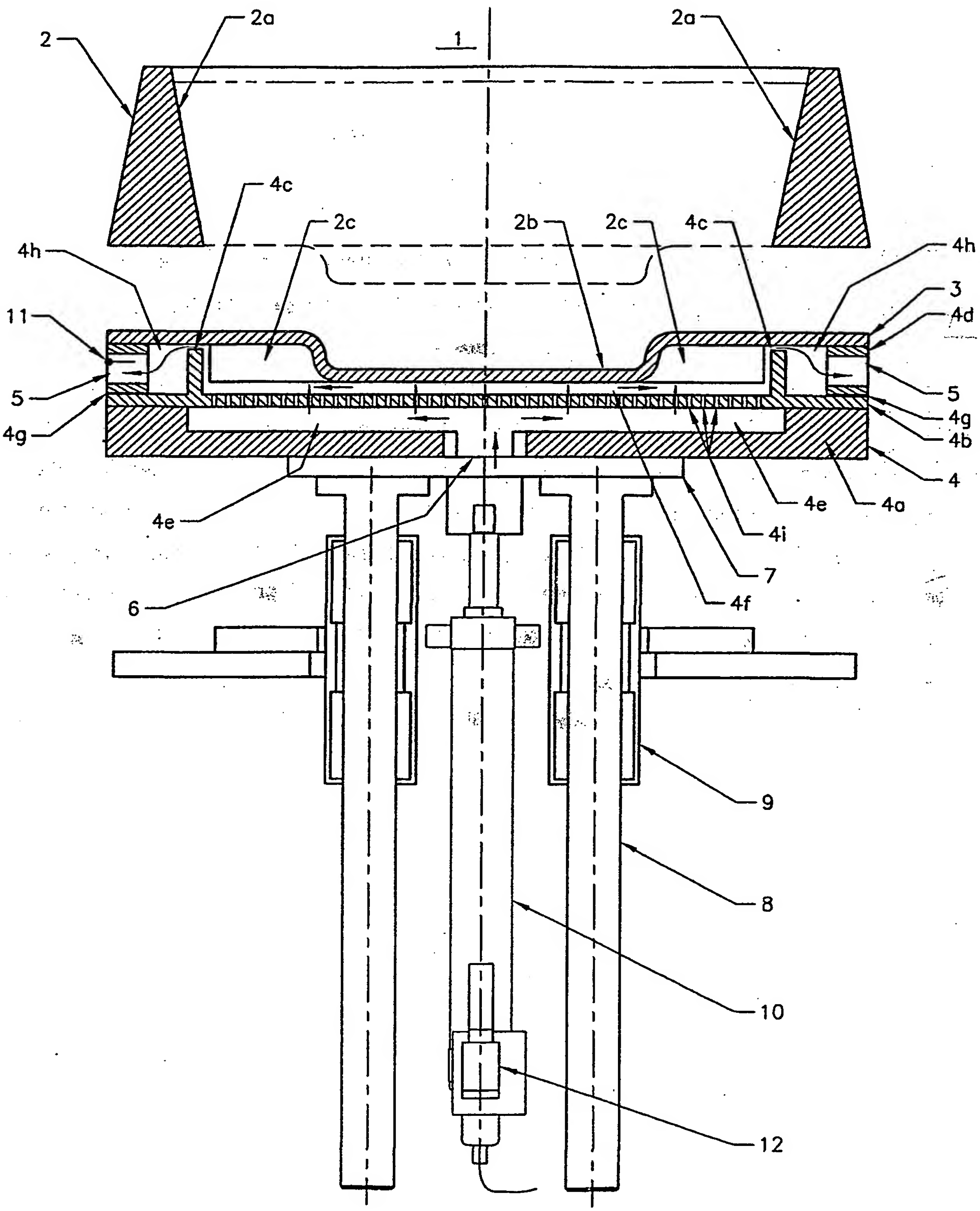
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FIGURE 1

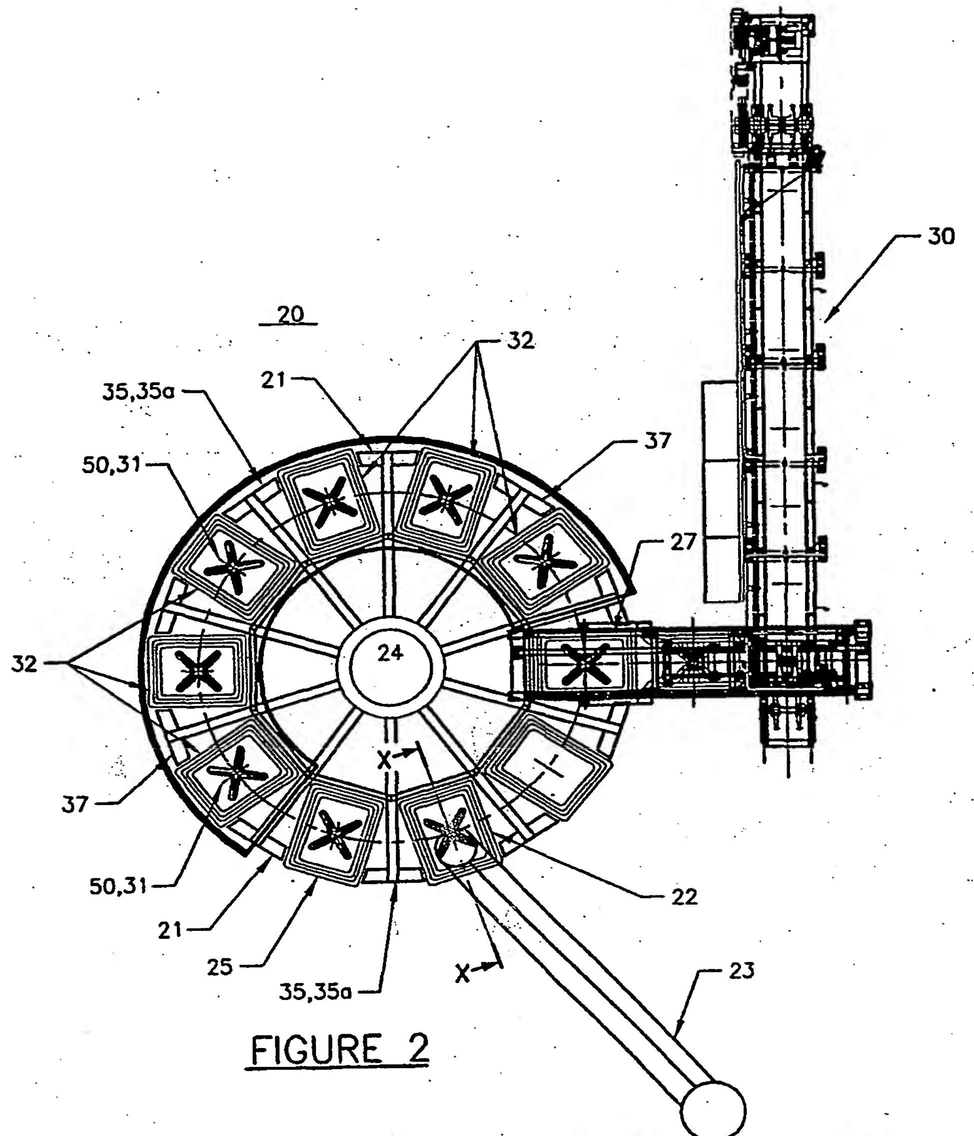

FIGURE 2

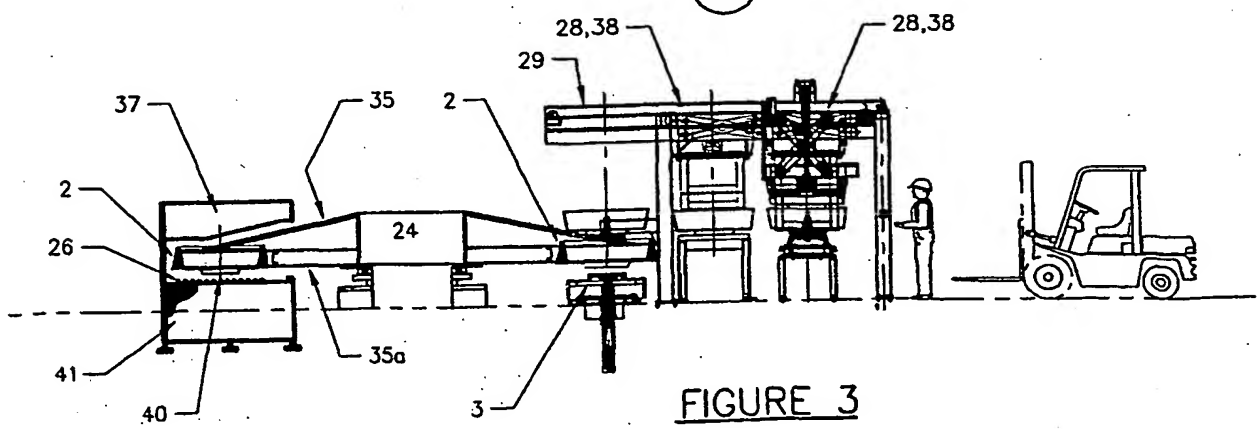

FIGURE 3

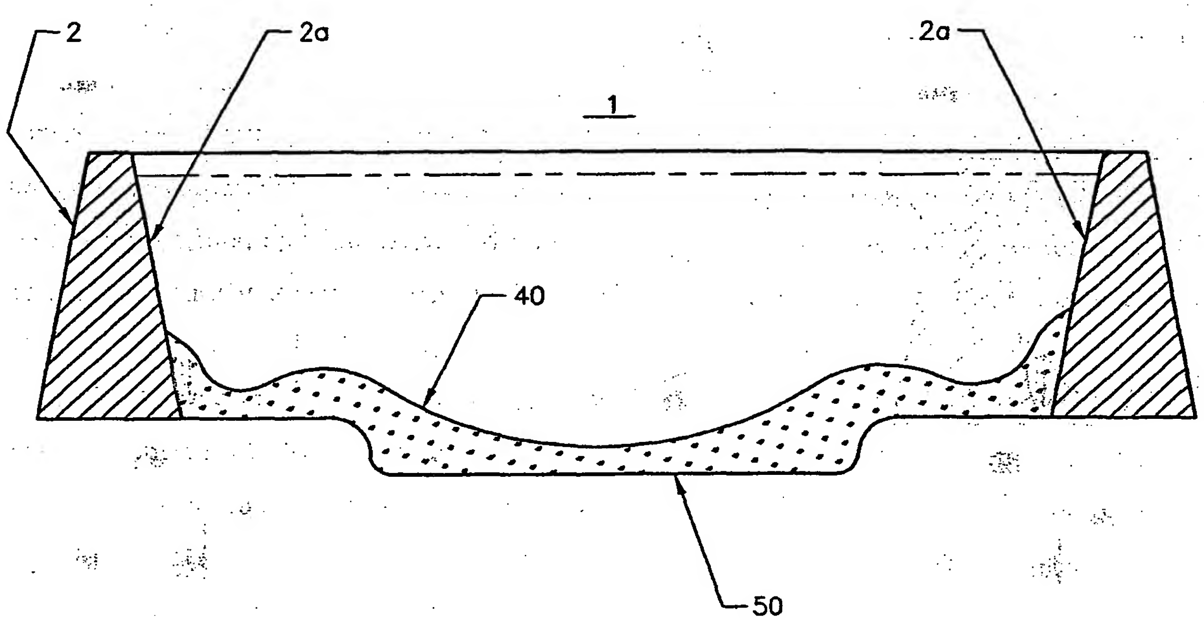

FIGURE 4

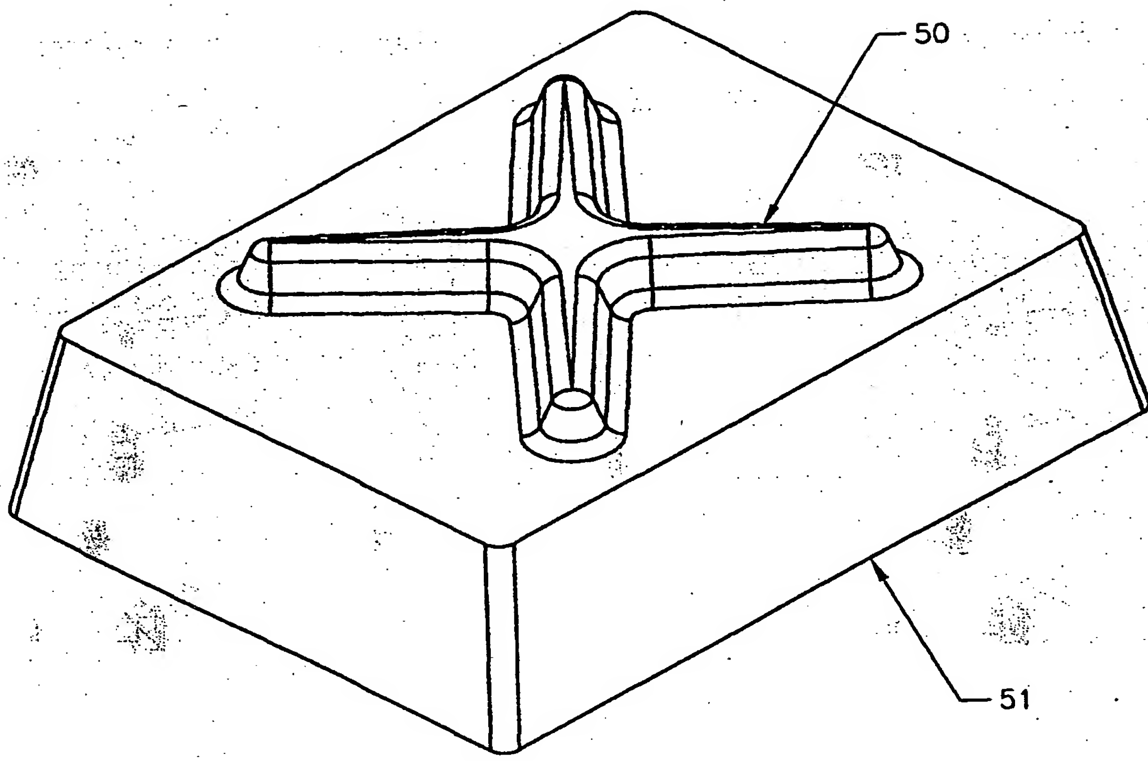

FIGURE 5

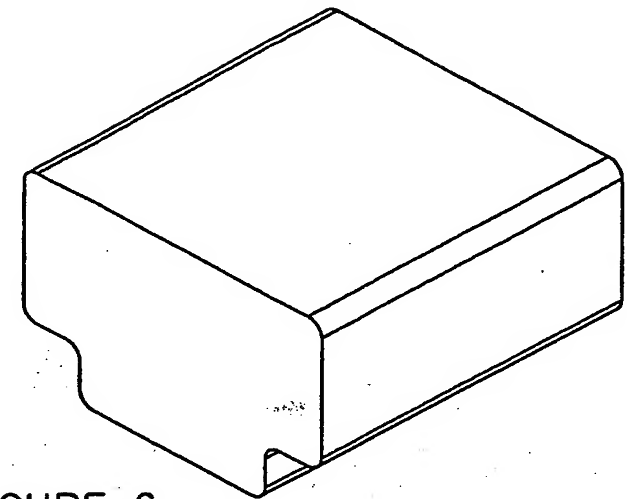

FIGURE 6

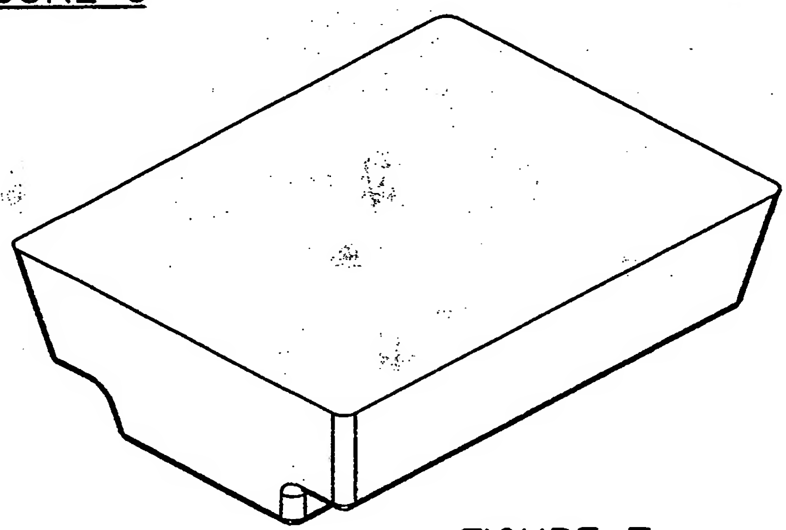

FIGURE 7

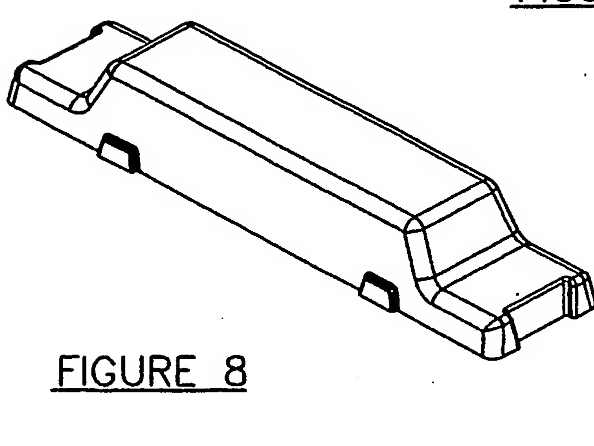

FIGURE 8

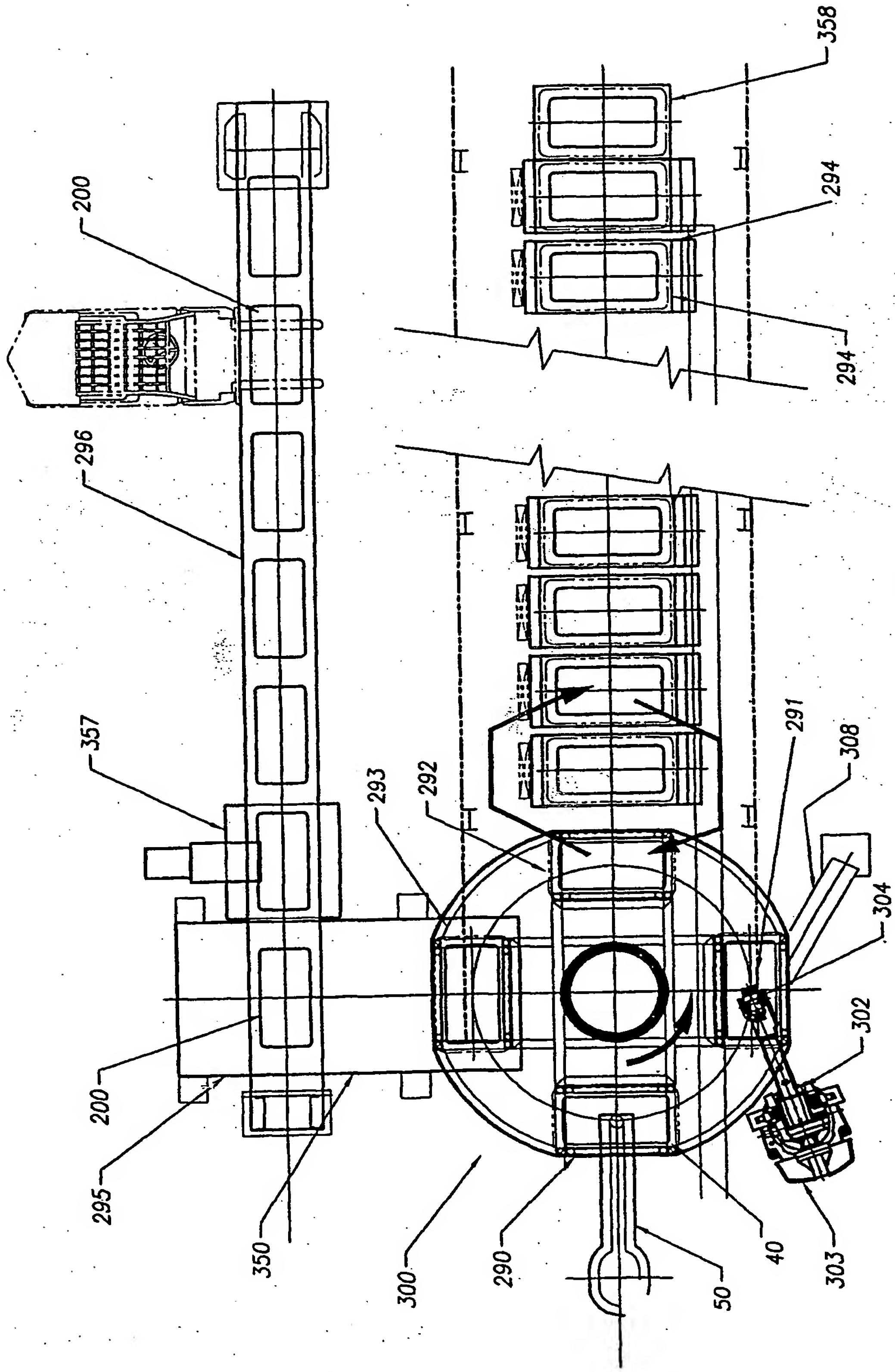
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FIGURE 9

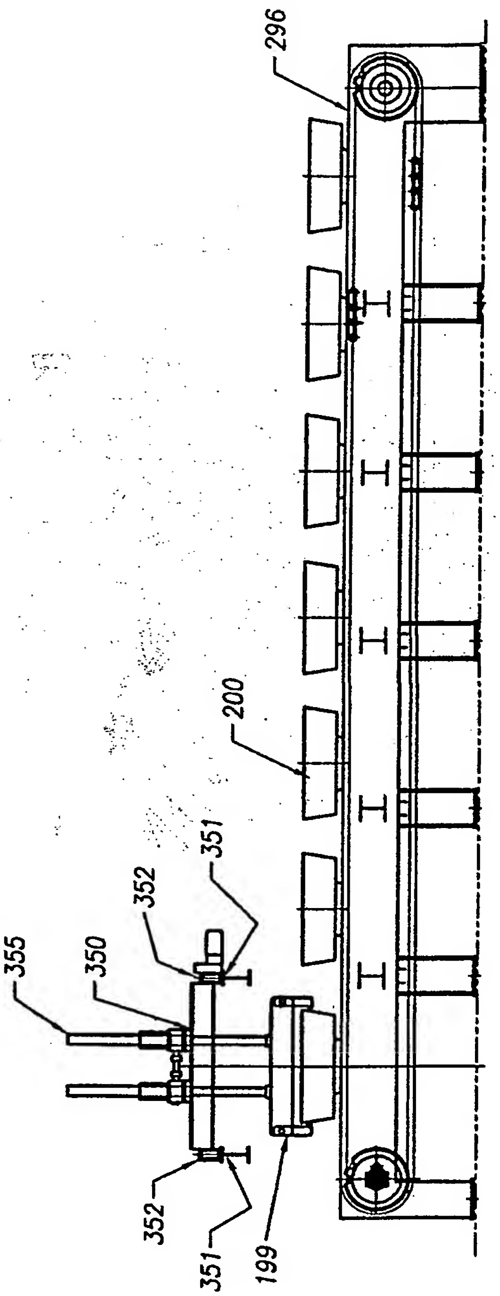

FIGURE 11

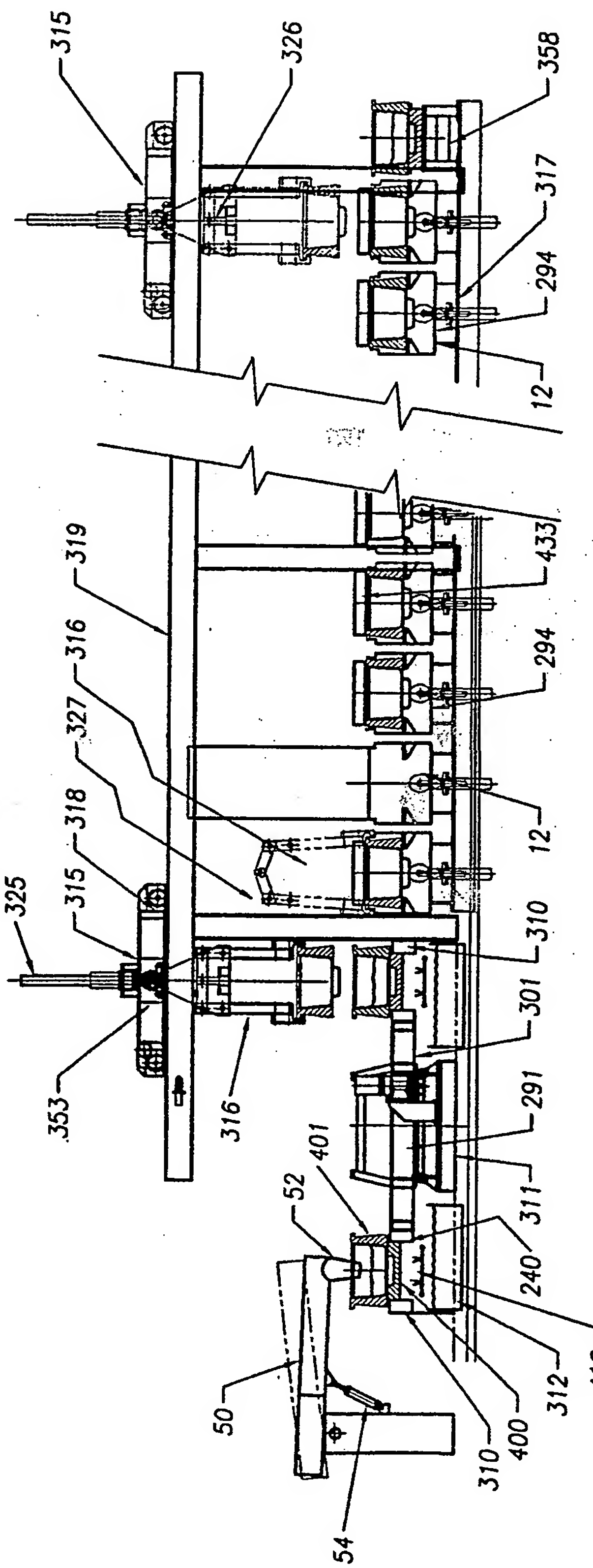

FIGURE 10

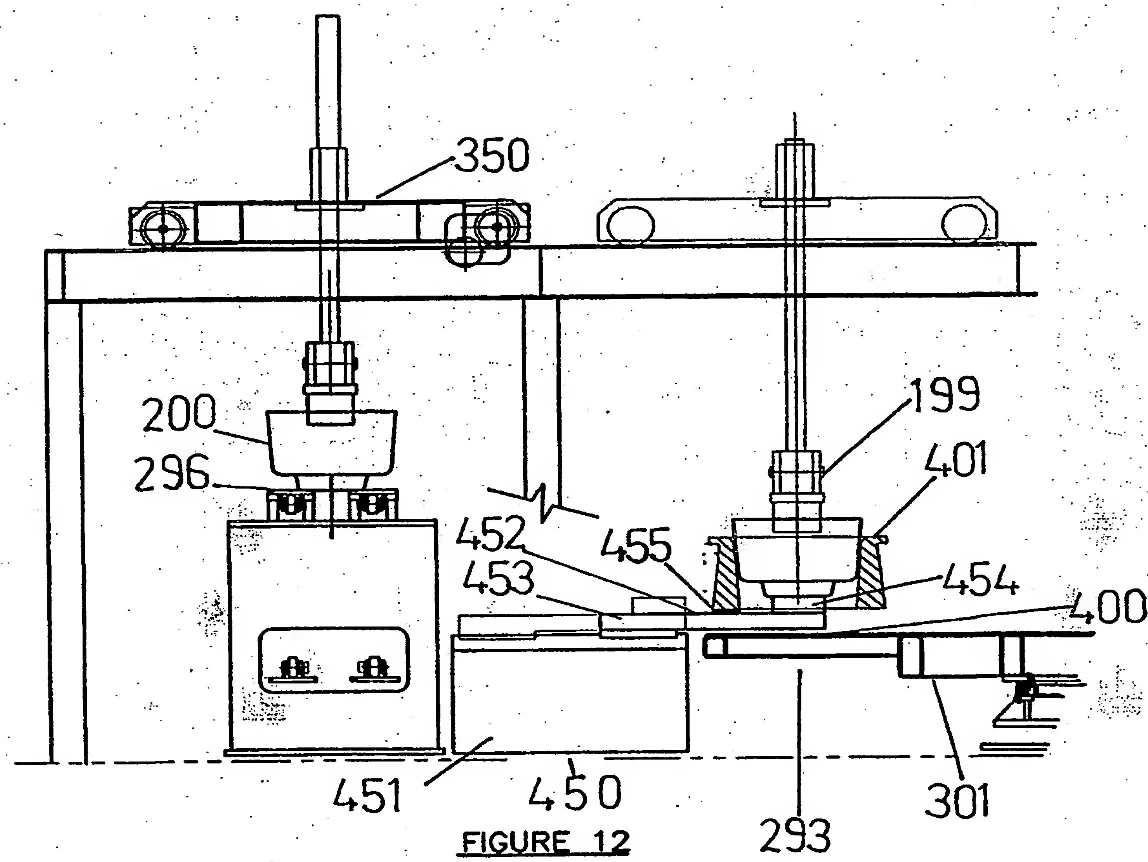

FIGURE 12

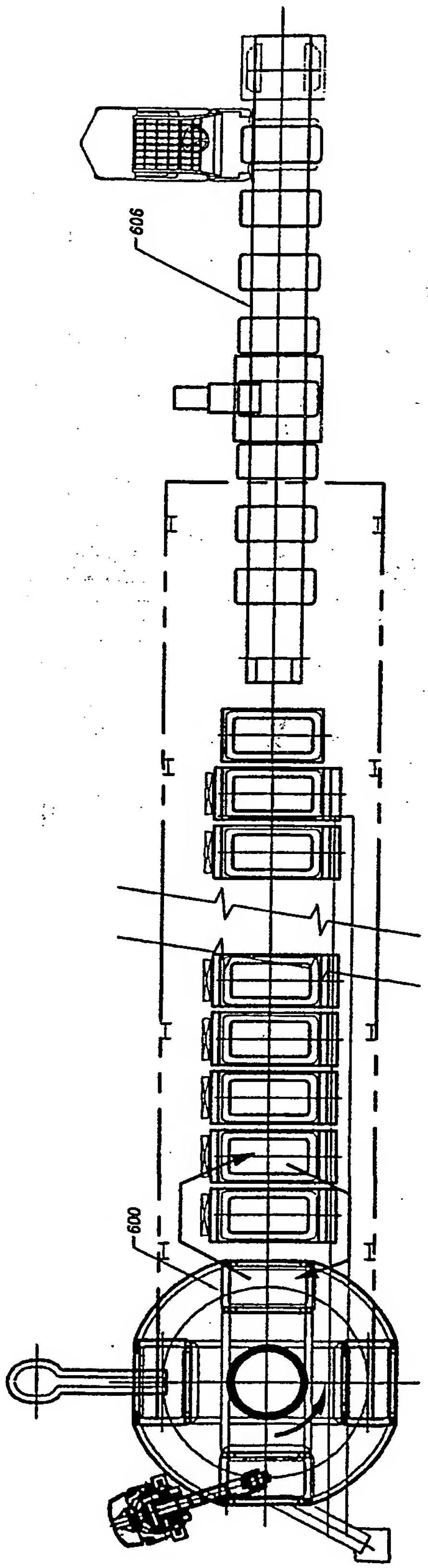

FIGURE 14

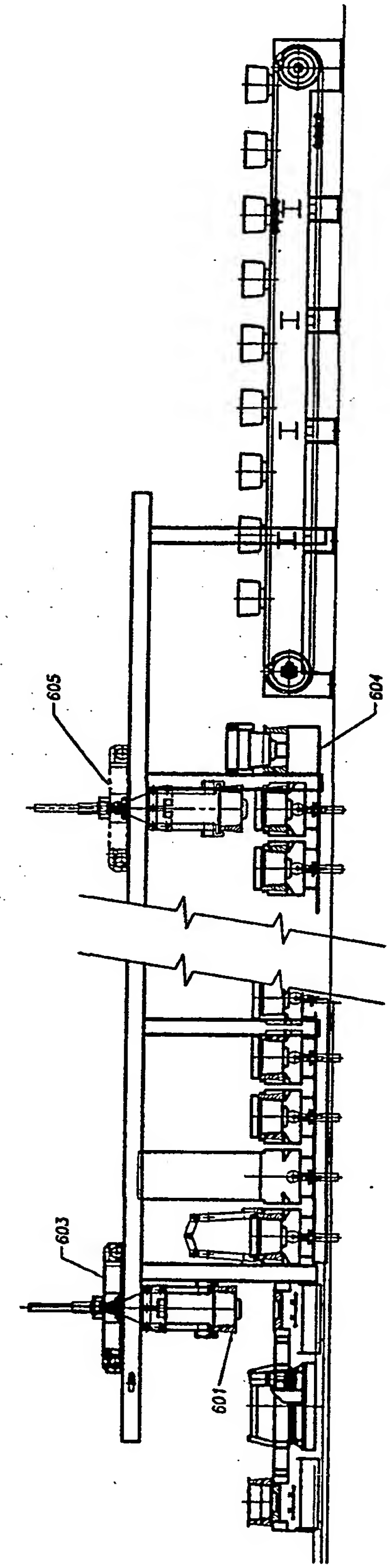

FIGURE 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU01/01165

A.	**CLASSIFICATION OF SUBJECT MATTER**
Int. Cl. ^{7}:	B22D 7/06, 15/04
According to International Patent Classification (IPC) or to both national classification and IPC	

B.	**FIELDS SEARCHED**
Minimum documentation searched (classification system followed by classification symbols)	
	IPC^7 AS ABOVE
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched	
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)	
	Derwent WPAT: IPC^7 as above and bottom+ or baseless

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 372945 B1 (Alcan International Ltd) 13 June 1990 Whole Document	
	EP 372947 B1 (Alcan International Ltd) 13 June 1990 Whole Document	
A	Derwent Abstract Accession No. 93-195293/24, Class P53, SU 1743675 A1 (Ferr Metal Work) 30 June1992 Abstract	

☒ Further documents are listed in the continuation of Box C ☒ See patent family annex

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	Document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	Earlier application or patent but published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	Document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	Document referring to an oral disclosure, use, exhibition or other means		
"P"	Document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 15 November 2001	Date of mailing of the international search report 19 NOV 2001
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer DAVID K. BELL Telephone No : (02) 6283 2309

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Derwent Abstract Accession No. 89-171912/23, Class P53, SU 1426694 A (Don Ferr Metal) 3 November 1986 Abstract	
A	Derwent Abstract Accession No. 54680D/30, Class P53, SU 778913 A (Zhdanov Metal Inst) 17 April 1978 Abstract	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU01/01165

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
EP	372945	AU	45948/89	BR	8906349	CA	1320335
		JP	2247045	NO	894913	NZ	231669
		US	5027882				
EP	372947	AU	45946/89	BR	8906351	CA	1320334
		JP	2247044	NO	894915	NZ	231670
		US	5148856				

END OF ANNEX

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

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(30) Priority Data:
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(72) Inventors; and
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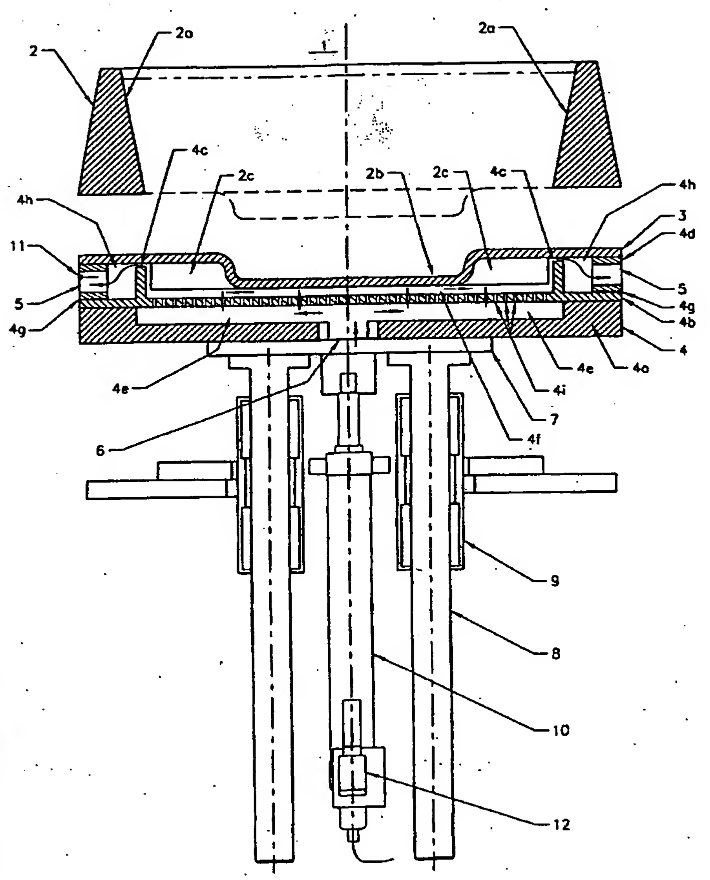
(74) Agents: **PERNAT, Alfred** et al.; Morcom Pernat, Suite 2, 334 Highbury Road, Mount Waverley, Victoria 3149 (AU).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian

[Continued on next page]

(54) Title: METAL CASTING PROCESS AND APPARATUS



(57) **Abstract:** An apparatus for casting of metals comprising, a bottomless mould (2), a base component (3) for providing a mould bottom, and cooling means (4) for cooling the base component, wherein the base component is locatable in registry with the bottomless mould to define a mould cavity for receiving molten metal, the cooling means facilitating the cooling of the base component to solidify at least a portion of the molten metal in contact with the base component.

WO 02/22292 A1

patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METAL CASTING PROCESS AND APPARATUS

Field of the Invention

The present invention relates to apparatus and processes for casting metals. In a particular non-limiting aspect, the invention relates to methods and apparatus particularly suitable for casting non-ferrous metals such as lead, tin, zinc, aluminium magnesium and their alloys. It also relates to components of such apparatus including moulds.

Background of the Invention

Typically, molten metals are cast into moulds to form ingots. The size of the ingot is dependent on the size of the mould. The molten metal is allowed to cool in the mould and on cooling adopts the general shape of the mould. Once the molten metal has sufficiently cooled, it can be removed from the mould. The ingots are then sold to manufacturers who in turn reheat the ingots to form molten metal, the molten metal being used as a feedstock for the manufacture of various products.

To achieve this simple procedure on a large scale, a typical system for casting of molten metals involves the use of a rotary casting table having a series of sections each containing a mould. A pouring station pours the requisite amount of molten metal into a mould located on the table. The mould is then indexed by the rotating movement of the table and is subsequently cooled at a cooling station generally by the application of a cooling fluid such as water. The cooling fluid can be sprayed onto the mould to facilitate cooling.

As the table turns, the mould is indexed to an extraction station where the now solidified ingot is removed from the mould and transferred to storage or for distribution to customers.

Although this and other methods are effective to a degree they often lead to the formation of central cavities in the ingot. As the molten metal cools, the partially formed ingot begins to pull away from the mould edges and bottom. These areas tend to cool more quickly than the middle portion and tend to create a central cavity within the ingot. The metal at the top of the ingot can solidify to form a cap when the top surface cools at a faster rate in comparison to the remainder of the molten metal. This in turn can lead to stresses on the top portion of the ingot which may result in the formation of cracks. The cracks can form a pathway to the cavity located within the ingot.

Ingots with a central cavity are potentially dangerous. In particular, if the ingots are stored outside, which is common practice, water or moisture can penetrate the ingot along a pathway formed by cracking, and can collect in a central cavity. Once an ingot containing moisture is re-melted, rapid vaporisation of the water in a confined space can cause an explosion which not only damages equipment, but potentially results in injury and loss of life.

The formation of a central cavity can be partly overcome by spraying the mould with cooling fluids such as water to ensure that the bottom and middle portions of the ingot solidify more quickly than the top. However, despite the use of such spraying techniques it has been found, this approach still leads to the formation of ingots with central cavities.

Additionally, as the mould base cools differentially with respect to the sides, stresses are induced upon the mould structure along specific areas located along the junctions joining the bottom of the mould with its sides. This in turn leads to the onset of structural weakness throughout the mould. Consequently the mould must be periodically replaced to ensure effective and safe casting operations.

Other known methods such as "vertical direct chill" casting can reduce the incidence of a central cavity, however these methods are expensive, labour intensive, require

more maintenance and are dangerous due to the potential for molten metal mixing with water.

The foregoing does not constitute an admission as to the state of common general knowledge in the art in Australia or the rest of the world as it existed as at the priority date of a claim of this application.

Disclosure of the Invention

The invention provides in one aspect an apparatus for casting of metals comprising,

a bottomless mould,

a base component for providing a mould bottom, and

cooling means for cooling the base component,

wherein the base component is locatable in registry with the bottomless mould to define a mould cavity for receiving molten metal, the cooling means facilitating the cooling of the base component to solidify at least a portion of the molten metal in contact with the base component.

Preferably the cooling means provides cooling for sufficient time to form a solidified metal base engaging the mould walls sufficient to support the weight of the remainder of the still molten metal, thereby allowing separation of the base component from the bottomless mould.

Preferably, the base component may be constructed of a material which can conduct heat readily away from the molten metal. The cooling means may comprise the base component and a base component cooling assembly. The base component is suitably a metal. Where the metal being cast is any one of aluminium, zinc, lead or magnesium the base component may suitably comprise copper, steel or cast iron. It may be coated with a material which reduces corrosion and oxidation by the air or the molten metal. In some instances the base component material may comprise aluminium. If aluminium is used it is preferred that the aluminium base material include a coating to resist corrosion and oxidation.

The base component may comprise the base component for a plurality of moulds. For example, where the base component comprises an elongate sheet of metal, several bottomless moulds may be sat upon the base component to form several mould cavities.

The fact that the base component is separate from the bottomless mould means that the rate of heat transfer from the bottomless mould to the cooled base component is less than would otherwise be expected if the two comprised an integral mould. Thus, the rate of cooling of the molten metal in contact with the interior walls of the bottomless mould will be less than the rate of cooling of the metal in contact with the base component. As a result the metal in contact with the base component solidifies first and forms a plug or base which closes off the bottom of the bottomless mould.

Suitably the bottomless mould has lesser heat transfer characteristics than the base component. Thus the bottomless mould may be comprised of a material which has a lower coefficient of heat transfer than the material of the base component which comes in contact with the molten metal. Alternatively or additionally the bottomless mould may include insulating material around at least a portion of its perimeter to reduce the effect of cooling caused by the outer walls being exposed to the atmosphere. To reduce the extent of cooling of the molten metal by the walls of the bottomless mould even further, a gasket may be interposed between the base component and the bottomless mould. The gasket may comprise insulating material. The insulating gasket reduces heat transfer between the bottomless mould and the cooled base component which in turn reduces the cooling effect of the walls of the bottomless mould on the molten metal.

A further approach to reduce the rate of cooling of molten metal not in direct contact with the base component is to provide a cover or roof over the top of the bottomless mould to reduce the cooling effect of air on the upper surface of the mould. When the metal being cast is magnesium a sealed cover has the additional advantage that it can provide a suitable chamber for the containment of a cover gas The gap between the

sealed cover and air may be filled with inert gas such as nitrogen to reduce the risk of oxidation. The roof or cover may include heating means to reduce the likelihood of the top surface of the metal cooling prematurely.

Preferably the bottomless mould has angled sides to aid in the retention of the base of a partially solidified ingot within the bottomless mould.

The cooling means may provide for the base component to be in contact with cooling fluids such as water. The cooling means may also include supply means to supply cooling fluid to the bottom of a partially formed ingot after the base component has been removed.

Preferably, the cooling fluids are at a temperature above the dew point to prevent condensation forming in the mould cavity. Alternatively or additionally the cooling fluids can be sprayed directly onto the base component and/or the bottom of an at least partially solidified ingot. The cooling fluids such as water may be sprayed onto the base component and/or the bottom of the ingot by a pump and spray nozzle or other appropriate means.

The cooling means may additionally or alternatively include the circulation of a cooling fluid such as water in contact with the base component by a pump or other appropriate means. Preferably a gallery formed by a base component cooling assembly mounted below and in contact with the bottomless mould directs the path of water in contact with the base component. Fluid enters the base component cooling assembly through an inlet, and circulates in contact with the base component in the region defined by the gallery. The now heated fluid is removed from the base component by an outlet. The fluid lowers the temperature of the base component by absorbing heat.

Preferably, the now heated fluid can be transferred via a passageway to a cooling area where it can be subsequently cooled and then if required, re-circulated through the base component cooling assembly.

Preferably, control monitoring means are located within the base component assembly. Preferably these monitoring means may be used to determine if the ingot is cooling correctly. They may operate by measuring the temperature of water after it has circulated through the base component cooling assembly.

Preferably, the base component can be located in registry with the bottomless mould by the use of a lift table. Preferably cylinders located under the lift table can be actuated by control means to bring the base component into registry with the bottomless mould. Control means can include pneumatic, hydraulic, electrical or mechanical means.

In a further aspect of the invention, a mould base is provided comprising a plurality of grooves located on the internal face of the mould base extending radially from a central point of the base. Thus in use the grooves define complementary ridges emanating from a central point of an ingot formed from the casting of solidifying material into the said mould, the solidifying material assuming the shape of the mould. An ingot produced from the mould has the ridges forming a cross shape on the ingot's lower surface. When the ingot is placed on a ground surface, the ridges provide clearance between the ground and the base of the ingot. The ridges are not long enough to extend to the edges of the ingot. This in turn allows a transporter such as a forklift to pick up the ingot from the bottom with the fork tynes of the forklift clear of the ends of the ridges.

The use of grooves in the mould base should assist with cooling because of the greater surface area. Whilst grooves are one method of providing an ingot in a shape which makes the ingot suitable for lifting by a forklift other ingot shapes known in the art may also be suitable. Examples of some alternative shapes will be shown in the accompanying drawings.

The invention provides in a further aspect, a method for casting of metals in a bottomless mould comprising the steps of,

placing a base component in registry with a bottomless mould to define a mould cavity for receiving molten metal,

casting the molten metal in the defined mould cavity, and

cooling the base component to solidify at least a portion of the molten metal.

Preferably, the cooling step can be for sufficient time to form a solidified metal base engaging the mould walls sufficient to support the weight of the remainder of the still molten metal.

The method may comprise the further step of removing the base component from the bottomless mould. This further step may be required if the depth of the mould is so great that the metal frozen above the base component shrinks and thereby loses intimate contact with the base component and hence the cooling effect of the base component is reduced. The depth of the molten metal cast can effectively determine whether it is preferred to improve cooling by removing the base component. Whilst this depth will vary from metal to metal, generally speaking a metal depth of at least 5cm, more preferably 10 cm, can be used as a rough rule of thumb for determining whether the base component should be removed prior to direct cooling of the bottom of the cast metal ingot.

Preferably, removal of the base component can occur after the formation of the solidified metal base engaging the mould walls sufficient to support the weight of the remainder of the still molten metal.

In another embodiment the invention provides an apparatus for the casting of metal comprising,

a mould assembly station including lifting means for bringing a base component into registry with a bottomless mould to form a mould cavity and for removing the base component out of registry with the bottomless mould,

a pouring station for pouring molten metal into the mould cavity,

cooling means for cooling the base component with cooling fluid and solidifying at least a portion of the molten metal in contact with the base component,

a cooling station for flowing cooling fluid directly against the molten metal which has solidified in contact with the base component after the base component has been brought out of registry with the bottomless mould, and

an extraction station for removing a solidified metal ingot from the bottomless mould.

The mould assembly station, pouring station and cooling means may all be at different locations, at the same location or a combination of any two of these possibilities.

Preferably the cooling means provides for sufficient time to form a solidified metal base engaging the mould walls sufficient to support the weight of the reminder of the still molten metal, thereby allowing removal of the base component from the bottomless mould.

The drive may include a driven linear or rotating platform. The bottomless moulds may be placed on the platform and indexed or conveyed to different stations. The platform may include a plurality of cradles for receiving the moulds. The drive may include control means to limit the disturbances to molten metal cast into the moulds.

The extraction station includes a removal means. The removal means may include an overhead crane or any other suitable pick and place apparatus. It may include one or more overhead rails for moving a crane trolley to a location above the drive. At this location it can pick up a solidified ingot and place it on a conveyor chain for transfer away from the drive.

Preferably one or more launders are provided for casting molten metal into the bottomless moulds. Each launder may fill a separate mould or may partially fill the same mould allowing the ingot to be poured in stages. The launder may have a plurality of outlets to pour more than one ingot at a time. The launder may be tiltable. It may include a compressible support such as spring loaded support or other equivalent, eg. hydraulically, electrically or pneumatically actuated support. The

launder support mechanism may be associated with control means for controlling the casting operation. The launder may be suitable for continuous and batch production.

Where the launder is used in association with the apparatus it will be located at a pouring station. The launder will operate to sequentially fill moulds indexed to the launder by the sequential drive.

Preferably a cooling station is located between the pouring station and the extraction station. It may extend for the entire travel of the bottomless mould between the two. Following removal of the base component the cooling station may provide for the bottom of the ingots to be in contact with cooling fluids such as water whilst being indexed to the delivery station. Cooling fluids such as water may be circulated around the ingots by a pump or other appropriate means. Alternatively, the cooling fluids such as water may be sprayed onto the ingots by a pump through a plurality of spray nozzles.

Preferably the apparatus includes a skimming station located between the pouring station and the extraction station. At the skimming station, dross may be removed from the molten metal cast into the mould either manually or with automatic machinery. When the apparatus includes both a skimming station and cooling station, the skimming station is preferably located between the pouring station and the cooling station. The skimming station may be integral with the pouring station.

As described above, the bottom component is removed once a solidified metal base engaging the wall of the mould has formed. Consequently, there is reduced stress on the mould since the bottom component and the upper portion of the mould are free to move independently. The cooling of the molten metal from the bottom can also reduce the incidence of producing metal ingots with internal cavities as the lower portions of the ingots solidify prior to the upper portions. The ability to apply a cooling fluid directly to the cast metal surface may allow the process to achieve a higher production rate than would otherwise occur if the base is not removed.

The incorporation of a bottomless mould as part of the apparatus can result in a casting apparatus capable of producing a substantially cavity free produce at a high production rate. The advantage of having a substantially cavity free ingot can reduce the subsequent operation costs to manufacturers of metallic products as the ingots do not require baking in an oven prior to use. Cavity free ingots are also safer to use as there is a reduced chance of water and molten metal interaction.

Detailed Description of the Preferred Embodiments

Figure 1 shows a cross-sectional view X-X of the apparatus shown in Figure 2 according to the invention;

Figure 2 is a plan view of a casting apparatus according to one embodiment including the apparatus of Figure 1;

Figure 3 is a side view of the apparatus shown in Figure 2;

Figure 4 is a cross-sectional view of the bottomless mould shown containing a partially solidified ingot of Figure 1 with a solidified metal base.

Figure 5 shows a perspective upside down view of an ingot cast using the apparatus shown in Figures 1 to 3;

Figures 6 to 8 show perspective views of alternative ingot shapes which may be cast according to the invention;

Figure 9 shows a plan view of an alternative casting apparatus according to the invention;

Figure 10 shows an elevational view of a first section of the casting apparatus of Figure 9 incorporating a carousel;

Figure 11 shows an elevational view of a second section of the casting apparatus of Figure 9 incorporating an ingot removal device and conveyor;

Figure 12 shows an elevational view of a demoulding assembly;

Figure 13 shows an elevational view of an alternative form of combined cooling facility and ingot removal facility; and

Figure 14 shows a plan view of an alternative form of combined cooling facility and ingot removal facility.

Referring to Figure 1, an apparatus 1 for casting molten metal according to the invention is shown. The apparatus 1 comprises a bottomless mould 2 generally rectangular or square in plan, with internal walls 2a and a cross shaped depression 2b. It also includes cooling fins 2c. The internal walls of the bottomless mould are sloped with respect to the vertical so that the ingot can be supported by the walls when the bottom of the ingot solidifies. A base component 3 and a cooling means 4 are arranged beneath the bottomless mould. The base component 3 is constructed of a heat conductive material, preferably copper. The base component and bottomless mould together define a mould cavity.

The cooling means includes a base component cooling assembly 4. The base component cooling assembly has outlets 5, and inlet 6. It comprises a base plate 4a which forms a closed cavity 4e with the perforated plate 4b mounted thereon. The perforations 4i in the perforated plate are arranged to allow fluid flow from the cavity 4e into the cooling gallery 4f formed between the bottom of the base component, the perforated plate and the baffle member 4c.

A spacer 4d and gasket 4g serve to space the baffle member from the base component and form an exit gallery 4h running around the outside of the cooling gallery.

A thermocouple 11 is located in the outlet to sense temperature changes in the cooling fluid. By sensing the temperature of cooling fluid through the outlet and comparing it with the temperature of the cooling fluid sensed to be entering the inlet it is possible to determine the degree of cooling and/or solidification of the ingot for a given fluid flow rate. It is therefore possible to determine the best time to remove the base component after a sealing plug of metal has formed in the bottom of the mould cavity. Cooling fluid such as water is circulated within the body of the base component by a pump (not shown) by entering via the inlet 6, following a path shown by the arrows and exiting via the outlets 5.

The base component 3 is located on a lifting table 7 supported by guide rails 8 located within guides 9. A lifting mechanism 10 engages the table 7.

In order to cast molten metal, the lifting mechanism 10 is actuated to lift the table 7 and hence the base component to bring it into registry with the bottomless mould to define an entire mould cavity for receiving molten metal. A lift sensor 12 senses when the base component abuts the bottomless mould and/or how much metal has been cast into the mould. The signals from the lift sensor can be used to control various operations such as the extent of lifting travel required of the lifting mechanism, the initiation of the casting of molten metal, the rate of casting and the cessation of casting when the required weight of metal has been cast.

The cooling means 4 facilitates the cooling of the base component 3 for a sufficient time to form a solidified metal base 40 engaging the mould walls 2a as shown in Figure 4. After the formation of the solidified base 40, the lifting mechanism 10 is reactivated to remove the base component 3 from the bottomless mould 2.

The formation of the solidified base 40 is accelerated by two factors. Firstly the base component 3 being made of heat conductive material including cooling fins 2c absorbs the heat from the molten metal contacting the base component 3. Secondly the circulating cooling fluid absorbs and removes the heat within the base component 3.

Figures 2 and 3 show an apparatus 20 for casting molten metal having a sequential drive for indexing bottomless moulds 2. The apparatus 20 consists of a rotating carousel 21 mounted by support arms 35 and 35a on a central support assembly 24. As is shown in Figure 2 the bottomless moulds 2 are located at points along the rotating carousel 21. The apparatus 20 in turn has several stations.

A casting station 22 includes the base component 3 previously described and a launder 23. The lifting mechanism 10 can be actuated to bring the base component 3 in registry with the mould walls 2a of the bottomless mould to define an entire mould cavity. Molten metal can now be introduced by the launder into the mould in the cavity as defined by the base component 3 and the bottomless mould 2.

The rotating carousel 21 is sequentially driven to index the mould containing the molten metal away from the casting station 22. The indexing is contingent on the formation of a solidified metal base 40 engaging the mould walls 2a. Once this occurs the solidified metal base 40 provides the bottom to the bottomless mould 2 and allows both the removal of the base component 3 by retraction of the lifting mechanism 10 and the indexing of the mould bottom containing partially solidified metal away from the casting station 22. As mentioned earlier the formation of the solidified metal base 40 is facilitated by the heat conductive properties of the base component 3 and the actions of the cooling means 4.

The carousel then rotates clockwise to index the bottomless mould 2 now filled with molten metal (but containing a solidified metal base 40) towards the extraction station 27.

As indexing occurs, the molten metal is indexed to a skimming station 25 to remove the dross from the molten metal cast into the mould.

Following removal of the dross, the bottomless mould 2 is again indexed towards the extraction station 27. A cooling station 32 lies between the casting station 22 and the extraction station 27. During indexing through the cooling stations the ingot bases are in contact with cooling fluids such as water. The cooling fluids such as water are sprayed onto the ingot bases by a pump (not shown) through a plurality of spray nozzles 26. The molten metal solidifies as it is indexed through the cooling station 32 to form a solid ingot within the body of the bottomless mould 1. A roof 37 is provided over the cooling station to prevent solidification of the top surface of the molten metal so that it solidifies from the bottom upwards. A reservoir 41 extends beneath the spray nozzles for collection and recycling of water.

After cooling the mould now containing an ingot, is indexed to an extraction station 27. The extraction station 27 includes a crane 28 in the form of a scissor lift 38 and overhead rails 29 for moving the crane 28 to a location above the rotating carousel 21.

At this location the crane 28 picks up the solidified ingot and places it on a conveyor chain 30 for transfer away from the rotary carousel 21. The conveyor may comprise a twin chain indexing conveyor which moves ingots to defined positions ready for removal by a forklift.

As is shown in Figure 2 the base component 3 has a plurality of grooves 31. The grooves 31 are located on the base component 3 face engaging the molten metal. Figure 5 shows how the grooves 31 form a cross shaped bottom ridge 50 on to the bottom of the ingot 51 as the molten metal solidifies.

The ridge provides clearance between the ingot bottom and a floor surface allowing the ingot to be picked up and removed by a forklift.

Figures 6 to 8 show conventional ingot shapes which may be case in various metal, particularly aluminium according to the invention. The ingot of Figure 6 is typically quite large being about 700kg in weight. It is known in the art as a TEEBAR. That shown in Figure 7 may have a weight in the range 300 to 1000kg and is known as a SOW. Finally that of Figure 8 may have a weight of about 3 to 50kg and is known as an INGOT.

Referring to Figures 9 to 12, the automatic casting machine 300 includes a carousel 301 provided with a pouring or casting station 290, a skimming station 291, a transfer station 292 and a delivery station 293 for ingot removal. A cooling area comprising a number of cooling tanks 294 is provided. This extends radially away from the transfer station. An ingot deposit station 295 having a delivery conveyor 296 and labelling and weighing station 357 are provided in association with the delivery station 293. An overhead crane assembly 297 connects the delivery station to the ingot deposit station.

The skimming station includes an automatic skimmer 302. Generally this will be in a form of a robot 303 operating a skimmer plate 304. A dross removal chute 308 is provided to dispose of dross removed by the automatic skimmer.

The transfer station 292 includes a first overhead crane assembly 315. The crane has a pair of pivotable crane arms 316 operable by an actuator 326 acting through toggle arms via the pivot 327. As can be seen from the drawing when the arms are in the vertical configuration they grab underneath the lip of the bottomless mould to support and carry the bottomless mould carrying a partially or fully solidified ingot. However, when the toggle arms are operated in the reverse direction, the crane arms splay outwardly to let go of the mould.

The crane is provided with wheels 318 which run along the rails 319 so that it can move from above the transfer station 292 to the cooling tanks 294 where it can pick up and put down moulds. The base 12 of each of the cooling tanks is fitted with a water cooling system 317. A lid 433 is also provided for each cooling tank.

The first crane lifting assembly including actuator, toggle arms and crane arms is pivotally mounted via the pivot 353 for reasons to become apparent. The hydraulic cylinders 325 act to raise and lower the crane lifting assembly.

The second overhead crane assembly 350 includes hydraulic cylinders 355 for raising and lowering the block lifting assembly 199 and the cast block or ingot 200 attached thereto. The crane moves between a position above the delivery station 293 to one above the delivery conveyor 296. It includes wheels 352 and rails 351 for this purpose.

The carousel itself includes four mould cradles 310 for supporting the base components 400 and the bottomless moulds 401 mounted on the base components. It also includes a support and drive mechanism 311 and a weighing assembly for weighing the metal being cast into a mould as it is cast by the launder 50. The carousel is controlled automatically and is powered by a variable speed electronic drive.

Water sprays 410 are arranged to spray water onto the base component. A reservoir 312 collects the sprayed water for recycling. The water sprays and reservoir may extend from the pouring station to the transfer station.

In a typical sequence of operations using the casting machinery shown in Figures 9 to 12, molten metal is poured from a fixed launder (not shown) into the tilting launder 50. The rate of delivery of molten metal through the funnel 52 of the tilting launder is controlled by the degree of tilt which is in turn dependent upon the weight of metal in the launder.

When the weight of metal poured into the mould cavity defined by the base component and bottomless mould as measured by the launder reaches a predetermined limit, the hydraulic cylinder 54 lifts the launder clear of the mould.

The carousel then rotates anti-clockwise to index the mould cavity now filled with molten metal to the skimming station 291. The acceleration and deceleration of the variable speed drive rotating the carousel is carefully controlled each time it indexes the moulds to a different station in order to minimise the surface wave actions induced in the molten metal.

The robot 303 of the automatic skimmer 302 moves a skimmer plate 304 across the surface of the mould to pick up dross and dump it in the dross removal chute.

Following removal of dross, the mould cavity is indexed to the transfer station 292. At the transfer station the overhead crane 315 through operation of the hydraulic cylinders 325 lowers the crane arms which are held in the splayed position by the actuator 326 as they are being lowered.

When the crane arms are in registry with the lip of the bottomless mould, the actuator 326 operating through a pivot by a toggle action moves the crane arms into gripping registry with the lip of a bottomless mould and the bottomless mould containing

partly solidified metal is subsequently lifted by actuation of the hydraulic cylinders 325 clear of the cradle 310 and the base component supported by the cradle.

The crane then travels along the rails 319 until it approaches an empty cooling tank 294. It decelerates to a stop above the empty tank and lowers the bottomless mould so that the base of the solidified metal directly contacts the water in the tank. The acceleration and deceleration of the crane is controlled to reduce disturbance of the molten metal. The pivot 353 provided in association with the assembly for holding the arms of the crane allows the crane holding the bottomless mould to freely sway from the vertical during the acceleration and deceleration phases. This swaying action in association with controlled acceleration/ deceleration serves to reduce the amount of disturbance felt by the molten metal in the mould during the travel to the cooling tank and hence minimises ripples.

After the bottomless mould has been placed in a cooling tank and the crane arms are retracted to their uppermost position, the crane moves to a tank where the mould has had sufficient time for cooling, and after the lid 433 has been tilted aside, picks up the bottomless mould containing a solidified ingot and deposits it on the base component 400 mounted on the cradle 310 of the carousel at the transfer station.

This cooled mould cavity containing the solidified ingot is then indexed to the delivery station 293 by the carousel. An extra station 358 may be provided for the placement of bottomless moulds for any desired purpose such as mould replacement.

At the delivery station a demoulding assembly 500 as shown in detail in Figure 12 pushes the ingot 200 upward out of the bottomless mould so that the sides of the ingot are accessible to be gripped by the arms of the block lifting assembly 199 and moved by the crane to the delivery conveyor 296. The empty mould cavity is indexed by the carousel to the casting station.

Referring to Figure 12, the demoulding assembly 450 is located between the delivery station 293 and ingot deposit station 295 described with reference to Figures 9 to 11.

The demoulding assembly 450 comprises a support table 451 which supports a secondary cradle assembly 452 movable between the position shown at the right of the drawing in dark lines to the position shown at the left in light lines.

The secondary cradle assembly includes a horizontal platform 453 provided with an elevation pad 454. It also includes a support pad 455 for supporting the base of the bottomless mould. The support pad extends through the plane of the page and at two places in a direction to the right and parallel to the plane of the page to underlie sufficient of the bottomless mould to provide stable support therefore when it is in position shown in the drawing.

The steps involved in operation of the demoulding assembly are listed below:-

(i) Initially the secondary cradle assembly is in the position shown in faint lines at the left of the page when a mould cavity containing an ingot is indexed to the delivery station 293 by the carousel 301.

(ii) The block lifting assembly 199 lifts the bottomless mould 401 containing an ingot away from the base component 400.

(iii) The secondary cradle assembly moves to the right so that the elevation pad 455 underlies the bottom of the ingot and the support pad 455 underlies the bottomless mould.

(iv) The block lifting assembly lowers and releases the bottomless mould so that the elevation pad 454 forces the ingot upwards to partially extend above the bottomless mould.

(v) The block lifting assembly moves to grip and raise the ingot 200 and the crane assembly 350 moves the ingot to be deposited on the delivery conveyor 296.

(vi) The block lifting assembly is returned to raise the bottomless mould from the secondary cradle assembly.

(vii) The secondary cradle assembly is retracted.

(viii) The block lifting assembly lowers the empty bottomless mould onto the base component and retracts.

(ix) The carousel indexes the next mould cavity containing an ingot to the delivery station and the process is repeated.

Referring to Figures 13 and 14 there is shown an alternative apparatus according to the invention in which the need for a separate delivery station on the carousel as has been described with reference to the earlier drawings is avoided by virtue of the fact that the delivery station is used to deliver bottomless mould cavities containing partially solidified ingots to a combined cooling and demoulding facility.

Thus in Figures 13 and 14, the transfer station 600 is provided with a primary overhead crane assembly 603 for removing and replacing mould cavities 601 from the carousel.

Initially the primary overhead crane assembly takes a bottomless mould containing a partially solidified ingot from the carousel leaving the base component of the mould cavity in place on the carousel.

The primary overhead crane assembly then deposits the bottomless mould in a cooling facility. It goes on to pick up a fully cooled bottomless mould from the cooling facility and moves it to a demoulding facility where a solidified ingot is pushed out of the bottomless mould and is picked up by the secondary overhead crane assembly 605 and taken to the delivery conveyor 606.

The primary overhead crane assembly then picks up the empty bottomless mould left at the demoulding facility 604 and returns it to rest upon a base component originally left at the transfer station to reform a mould cavity. This is indexed back to the pouring or casting station and the entire cycle as per the previous general description repeated.

Whilst the description has often referred to the use of a carousel for indexing bottomless moulds, it is to be appreciated that any form of sequential drive properly configured may be used in place of a carousel.

The word "comprising" and forms of the word "comprising" as used in this description does not limit the invention claimed to exclude any variants or additions. Modifications and improvements to the invention will be readily apparent to those skilled in the art. Such modifications and improvements are intended to be within the scope of this invention.

Claims

1. An apparatus for casting of metals comprising,

a bottomless mould

a base component for providing a mould bottom, and

cooling means for cooling the base component,

wherein the base component is locatable in registry with the bottomless mould to define a mould cavity for receiving molten metal, the cooling means facilitating the cooling of the base component to solidify at least a portion of the molten metal in contact with the base component.

2. Apparatus according to claim 1 wherein the cooling means comprise the base component and a base component cooling assembly, both in combination forming a gallery for circulation of cooling fluid in contact with the base component.

3. Apparatus according to claim 1 wherein the bottomless mould has sides which are angled so that they become closer together nearer the bottom of the bottomless mould whereby to aid in the retention of the base of a partially solidified ingot within the bottomless mould.

4. Apparatus according to claim 3 comprising,

a mould assembly station including lifting means for bringing the base component into registry with the bottomless mould to form a mould cavity and for moving the base component out of a position of registry with the bottomless mould,

a pouring station for pouring molten metal into the mould cavity,

a cooling station for flowing cooling fluid directly against the molten metal which has solidified in contact with the base component after the base component has been brought out of registry with the bottomless mould, and

an extraction station for removing a solidified metal ingot from the bottomless mould.

5. Apparatus according to claim 4 comprising a sequential drive for indexing the bottomless mould to the different stations in a continuous repeatable circuit.

6. Apparatus according to claim 5 wherein the sequential drive comprises a carousel.

7. Apparatus according to claim 6 wherein the pouring station and mould assembly station are located at the same indexed position on the carousel.

8. Apparatus according to claim 5 wherein the cooling means comprise the base component and a base component cooling assembly, both in combination forming a gallery for circulation of cooling fluid in contact with the base component.

9. Apparatus according to claim 5 wherein the cooling station comprises,

a plurality of nozzles for spraying water onto the base of a partially solidified ingot,

at least one of a roof for covering the upper surface of the molten metal in the bottomless mould and heating means for heating the upper surface of the molten metal in the bottomless mould, and

a reservoir arranged beneath the plurality of nozzles for receiving water deflected off the base of the partially solidified ingot.

10. Apparatus according to claim 1 wherein the base component comprises a mould base provided with a plurality of grooves located on a surface of the base component forming the interior of the mould cavity, the grooves extending radially from a central point on the base component.

11. Apparatus according to claim 10 wherein the grooves form a cross.

12. Apparatus according to claim 1 wherein the base component includes a plurality of cooling fins.

13. Apparatus according to claim 5 wherein the extraction station comprises a lift for removing an ingot from the bottomless mould and an indexing conveyor arranged to receive an ingot from the lift.

14. Apparatus according to claim 13 wherein the lift comprises a scissor lift.

15. Apparatus according to claim 5 wherein the lifting means include a weight sensor for sensing the weight of molten metal cast into the mould cavity.

16. A method for casting of metals in a bottomless mould comprising the steps of,

placing a base component in registry with a bottomless mould having mould walls to define a mould cavity for receiving molten metal,

casting the molten metal in the defined mould cavity, and

cooling the base component to solidify at least a portion of the molten metal.

17. A method according to claim 16 wherein,

the cooling step is for sufficient time to form a solidified metal base from the molten metal for engaging the mould walls to support the weight of the remainder of the still molten metal,

the base component is removed to permit direct access to the bottom of the solidified metal base, and

cooling fluid is applied directly to the solidified metal base.

18. A method according to claim 17 wherein the depth of the molten metal cast into the mould cavity is at least 5cm.

19. A method according to claim 18 wherein the depth of the molten metal cast into the mould cavity is at least 10cm.

20. Apparatus according to claim 1, having a sequential drive for indexing moulds provided thereon to a plurality of stations, the plurality of stations including:-

a pouring station for casting molten metal into the mould cavity;

a separate transfer station provided with transfer means for lifting the bottomless mould containing a partially solidified molten metal cast into the mould at the pouring station to a cooling facility separate from the sequential drive allowing for the static cooling of the molten metal in an area remote from the sequential drive and for returning the bottomless mould to the sequential drive.

21. Apparatus according to claim 20 wherein the transfer means are arranged to lift the bottomless mould from the sequential drive, leaving the base component on the sequential drive and to return the bottomless mould containing a solidified ingot after cooling at the cooling facility to the transfer station to rest on a base component the apparatus also comprising an extraction station provided with removal means for removing a solidified ingot from the mould cavity before the mould cavity is returned to the pouring station by the sequential drive.

22. Apparatus according to claim 20 including a skimming station located intermediate the pouring station and transfer station, the skimming station being provided with means for skimming dross from molten metal contained in a mould cavity.

23. Apparatus according to claim 20 wherein the pouring station includes a launder for delivering molten metal to a mould cavity and weighing means for weighing the weight of metal delivered to the mould, the launder having valve means which are adapted to cut-off delivery of molten metal to the mould when the weighing means registers a weight of metal in the mould at or beyond a predetermined weight limit.

24. Apparatus according to claim 20 wherein,

the cooling facility includes an extraction station for removing a solidified metal ingot from the bottomless mould and transferring it to a discharge area leaving an empty bottomless mould,

the transfer means is arranged to return the empty bottomless mould to register with a base component held on the sequential drive at the transfer station to form a mould cavity, and

the sequential drive is arranged to index the mould cavity to the pouring station.

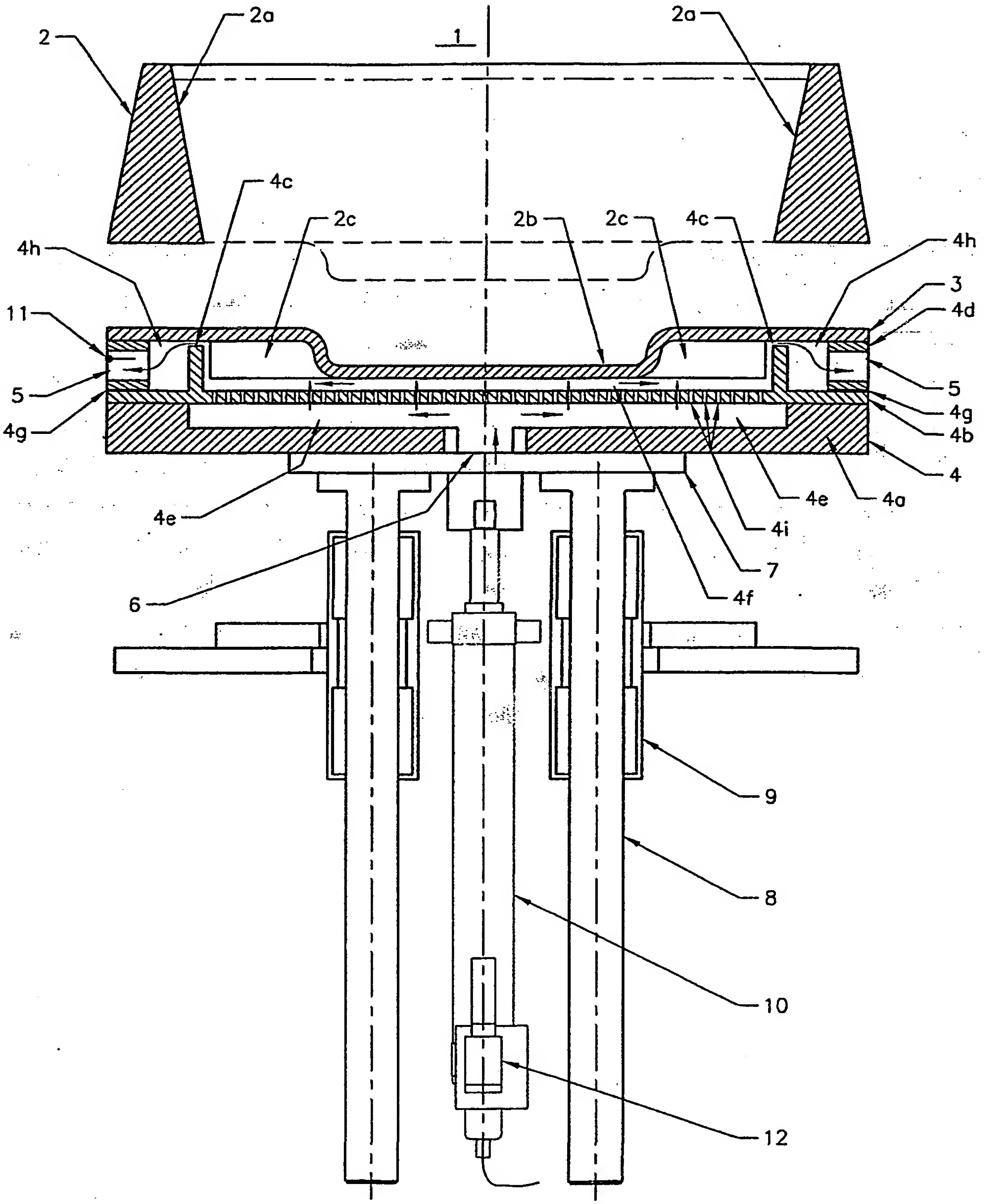

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FIGURE 1

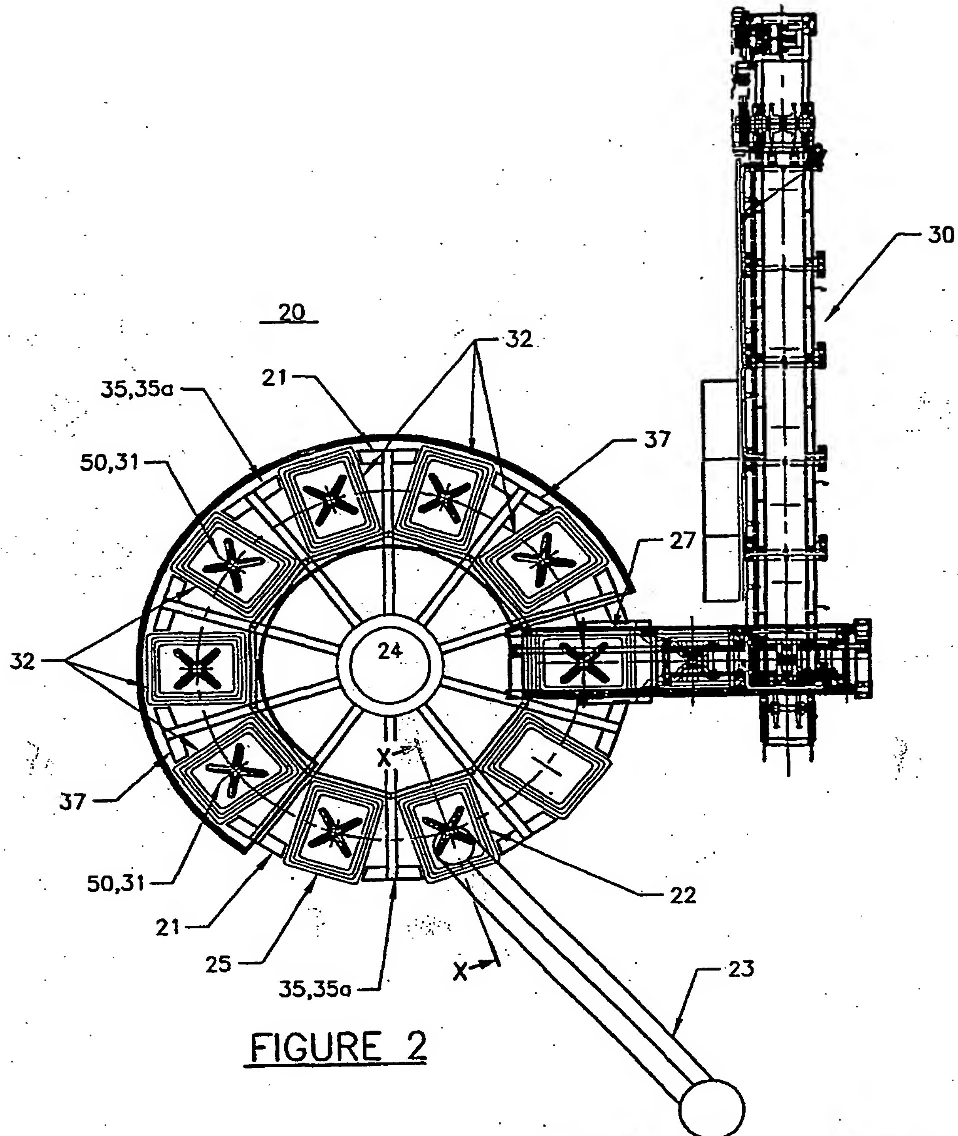

FIGURE 2

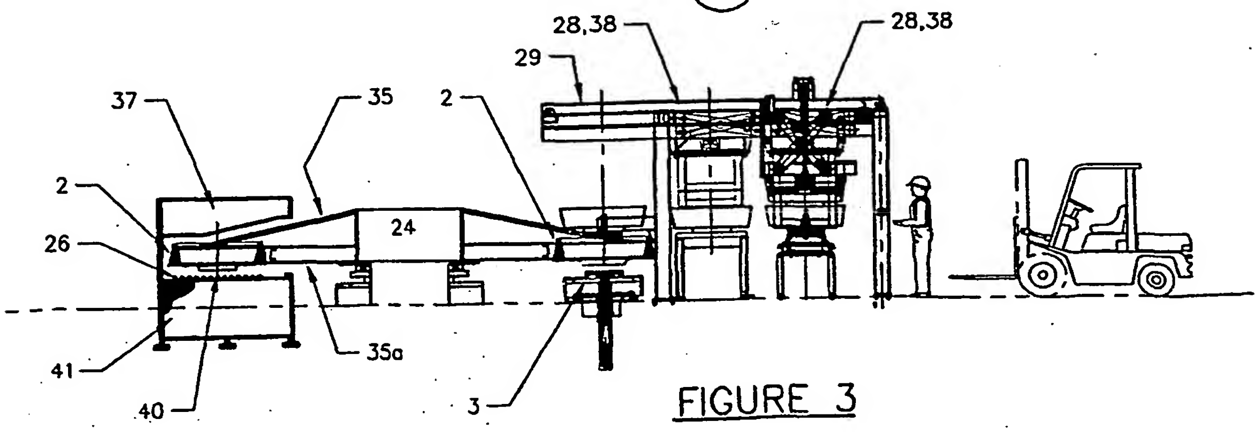

FIGURE 3

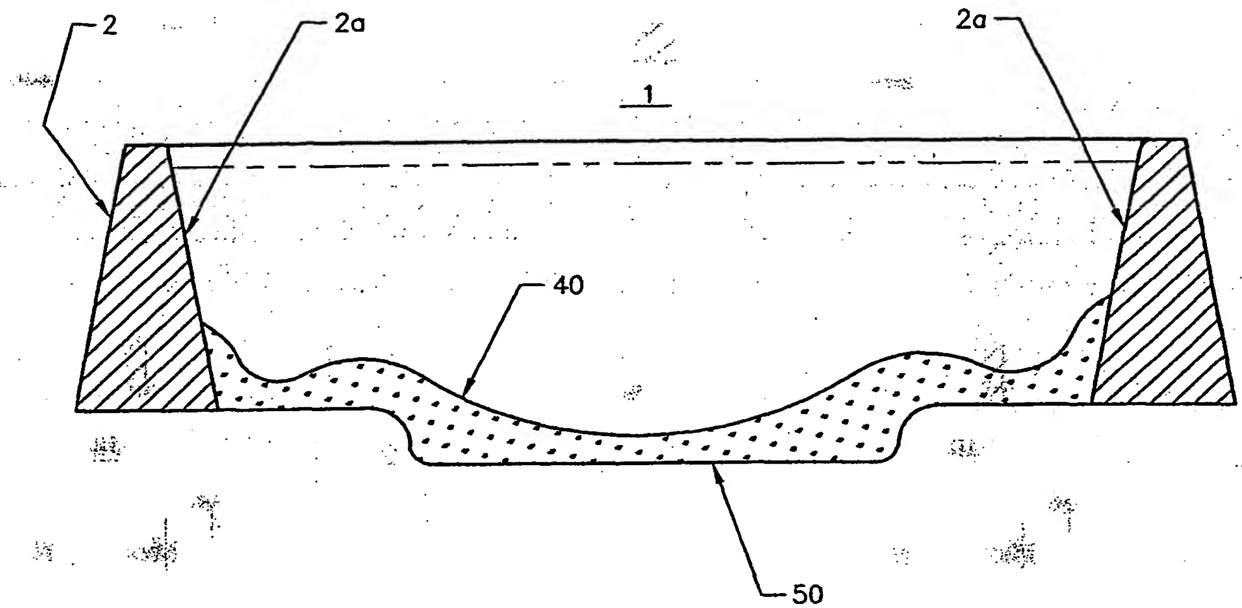

FIGURE 4

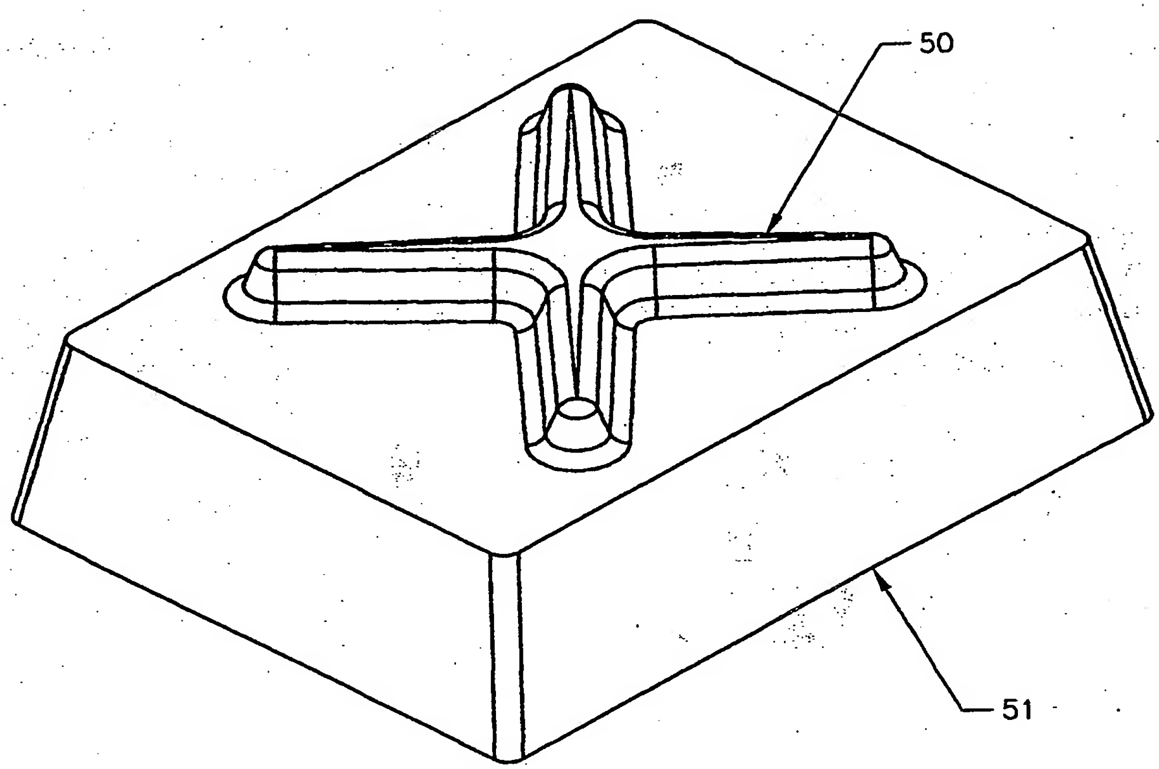

FIGURE 5

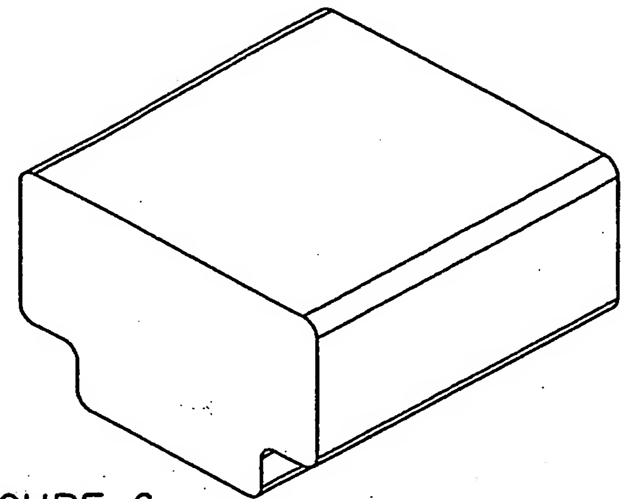

FIGURE 6

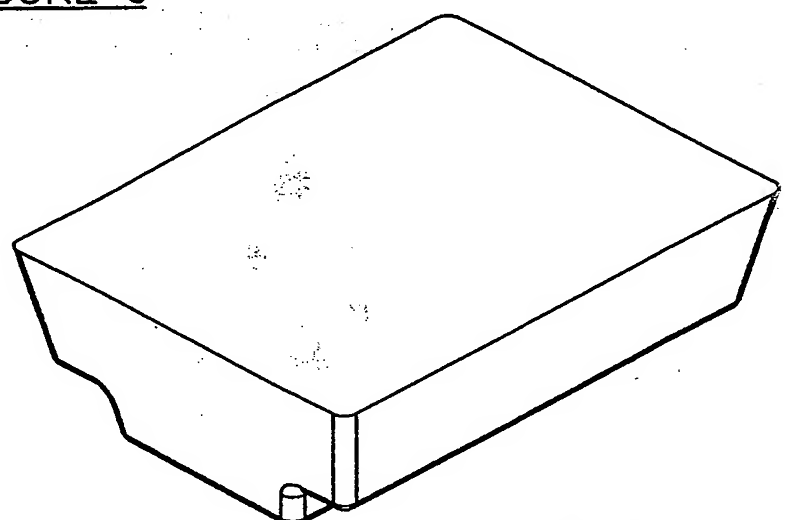

FIGURE 7

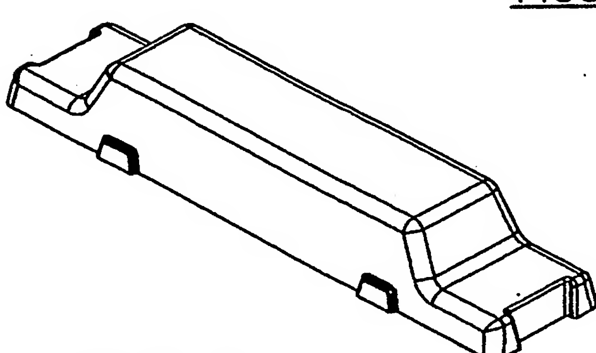

FIGURE 8

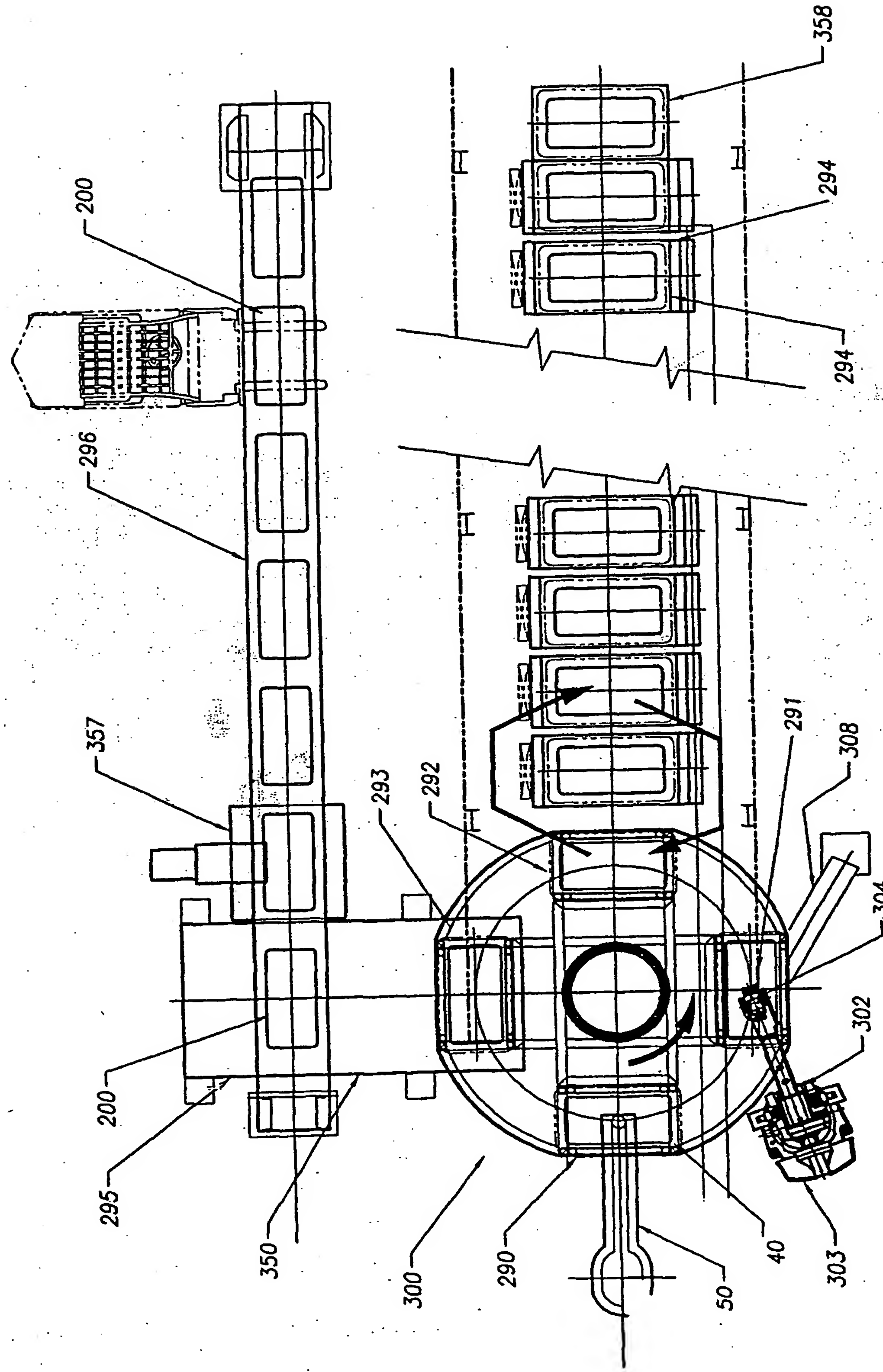
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FIGURE 9

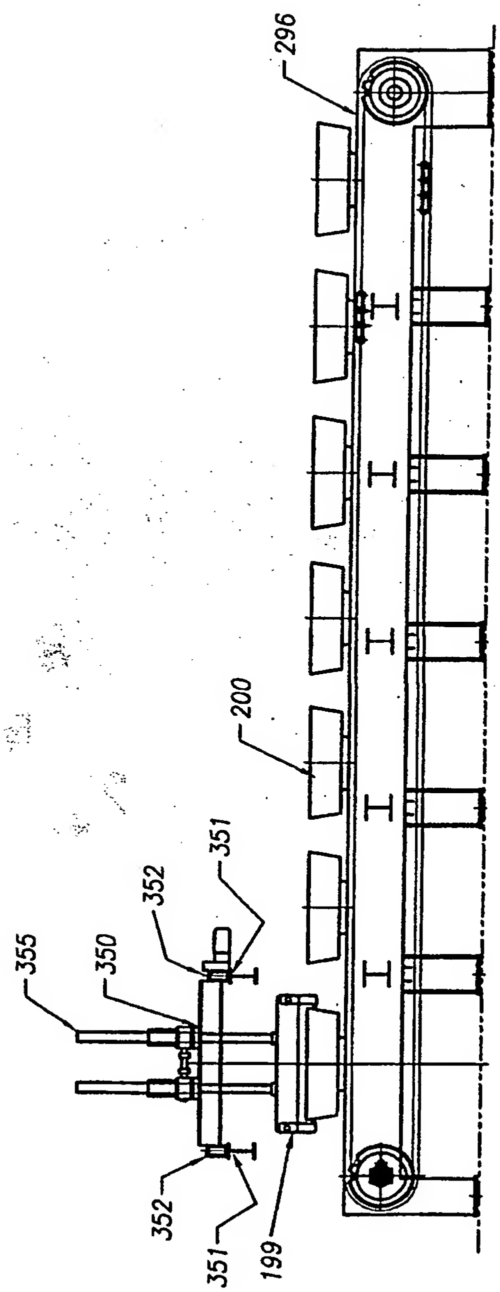

FIGURE 11

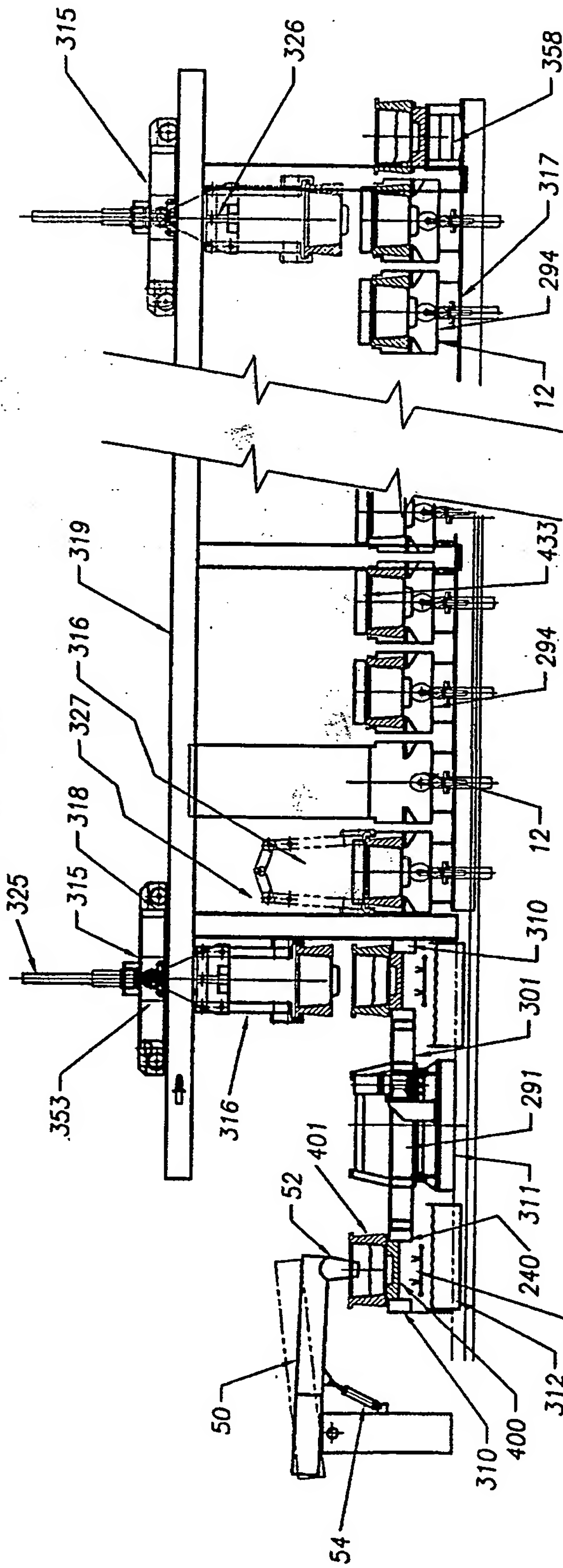

FIGURE 10

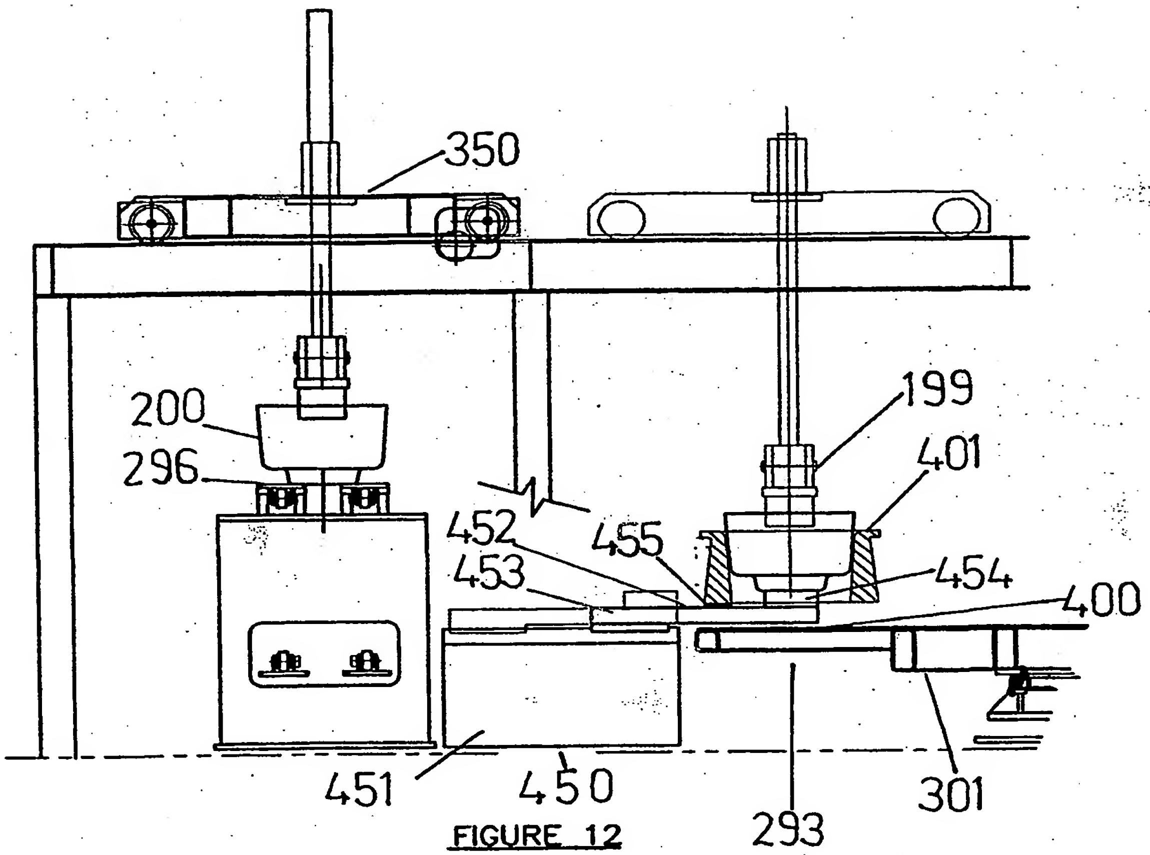

FIGURE 12

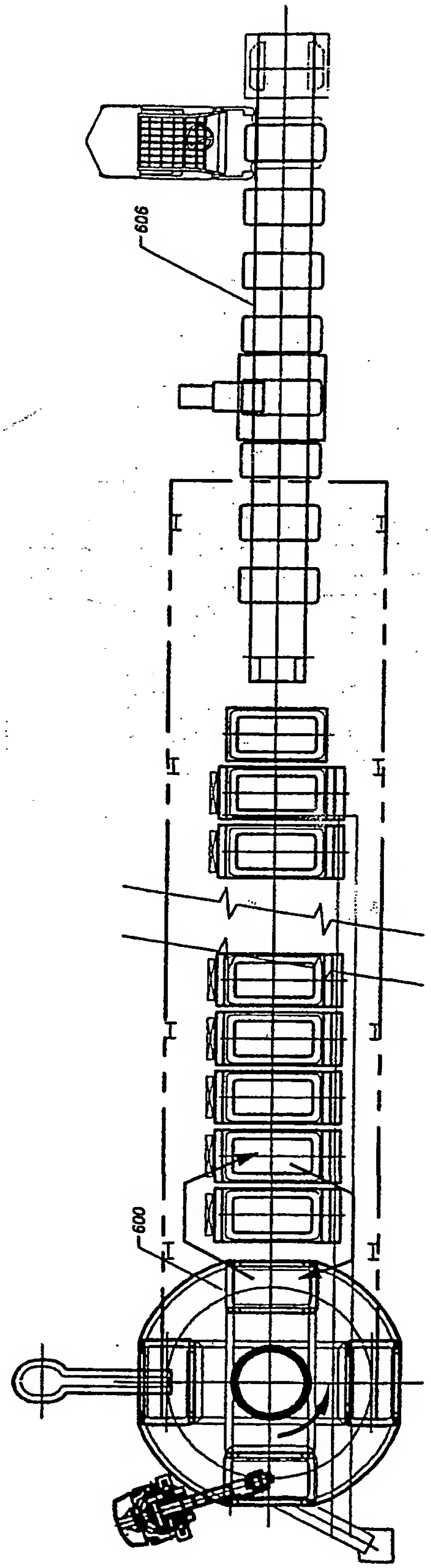

FIGURE 14

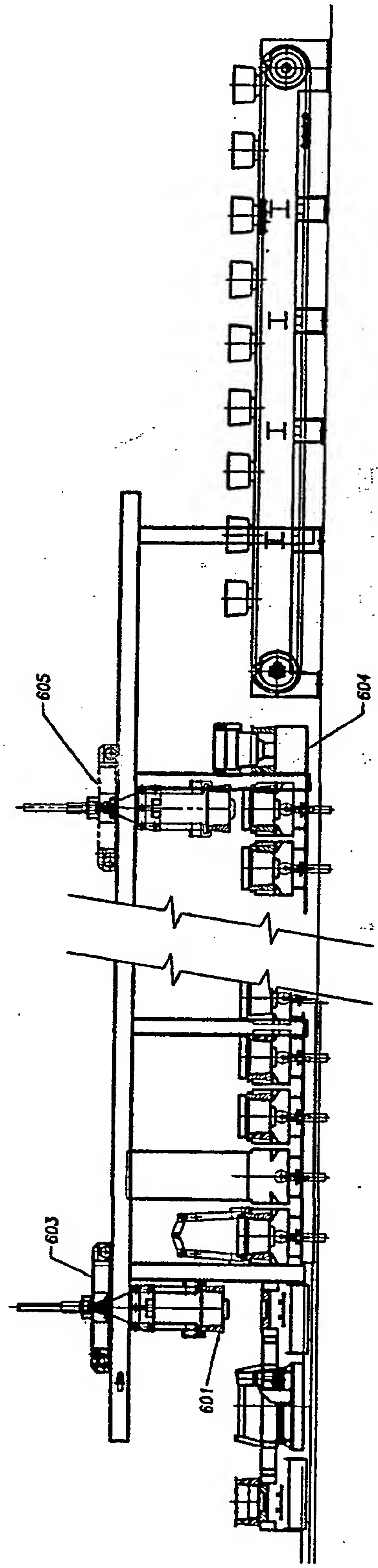

FIGURE 13

INTERNATIONAL SEARCH REPORT	International application No. PCT/AU01/01165

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: B22D 7/06, 15/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7 AS ABOVE

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Derwent WPAT: IPC7 as above and bottom+ or baseless

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 372945 B1 (Alcan International Ltd) 13 June 1990 Whole Document	
	EP 372947 B1 (Alcan International Ltd) 13 June 1990 Whole Document	
A	Derwent Abstract Accession No. 93-195293/24, Class P53, SU 1743675 A1 (Ferr Metal Work) 30 June1992 Abstract	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" Document defining the general state of the art which is not considered to be of particular relevance

"E" Earlier application or patent but published on or after the international filing date

"L" Document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" Document referring to an oral disclosure, use, exhibition or other means

"P" Document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 15 November 2001	Date of mailing of the international search report 19 NOV 2001
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer DAVID K. BELL Telephone No : (02) 6283 2309

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU01/01165

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Derwent Abstract Accession No. 89-171912/23, Class P53, SU 1426694 A (Don Ferr Metal) 3 November 1986 Abstract	
A	Derwent Abstract Accession No. 54680D/30, Class P53, SU 778913 A (Zhdanov Metal Inst) 17 April 1978 Abstract	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU01/01165

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
EP	372945	AU	45948/89	BR	8906349	CA	1320335
		JP	2247045	NO	894913	NZ	231669
		US	5027882				
EP	372947	AU	45946/89	BR	8906351	CA	1320334
		JP	2247044	NO	894915	NZ	231670
		US	5148856				

END OF ANNEX